Pearl Harbor Wetlands Inventory

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Table of Contents

Chapter 6 (continued)

Introduction

Report Organization

The previous inventory of wetlands in Pearl Harbor (ACOE, 1999) provided a descriptive overview of wetlands arranged by "segments" that divided the Pearl Harbor coastline in clockwise order from the west side of the Pearl Harbor entrance channel (Pu'uloa) to the east side of the channel (Fort Kamehameha). Here, we follow a similar sequencing for the Pearl Harbor wetland descriptions. However, we utilize different segment boundaries in order to better balance the amount of text and to better collate wetlands on Navy property versus those not on Navy property. The following "segments" are used in this report:

Chapter 1. Iroquois Point Lagoon to Honouliuli NWR (Navy wetlands)
Chapter 2. West Loch (north and west shore)
Chapter 3. Waipi'o Peninsula (Navy wetlands)
Chapter 4. Middle Loch and Pearl City Peninsula (Navy wetlands)
Chapter 5. North Shore of East Loch: Waiau to Kalauao Stream
Chapter 6. East Loch (east shore) and Ford Island (Navy wetlands)

The introduction to this report presents definitions for wetlands and a general discussion of wetlands that occur in the Pearl Harbor area. Approach and methodologies used in the report are discussed at length. Much of the discussion that follows attempts to clarify wetland definitions as they pertain to features in and around Pearl Harbor. While what is and is not a wetland should logically be at the heart of the scope-of-work for this project report, in the final analyses, the question is really peripheral to establishing legal responsibility for respecting and caring for aquatic habitats on Navy property. In essence, nearly all natural aquatic environments in and around Pearl Harbor are encompassed by Clean Water Act definitions of "special aquatic sites" (Federal Register, 1980) and therefore are jurisdictional.[1]

Previous Reports ~ In addition to the ACOE, 1999 inventory of Pearl Harbor wetlands, a series of separate reports (for example, Brunner, 1999; Char, 2000) covering various lands under Navy jurisdiction were prepared as appendices to the Pearl Harbor Integrated Natural Resources Management Plan (PHINRMP; Helber Hastert & Fee, 2001) and the INRMP for the Naval Magazine Pearl Harbor (NAVFACENGCOM, 2001). These sources and several earlier wetland

[1] Useful in clarifying federal jurisdiction in aquatic environments is knowledge of the six categories of "special aquatic sites" listed by EPA (Federal Register, 1980): 1) sanctuaries and refuges, 2) wetlands, 3) mudflats, 4) vegetated shallows, 5) coral reefs, and 6) riffle and pool complexes in streams. All are subject to provisions of the Clean Water Act.

inventory reports (Ahuimanu Productions, 1977; Elliott & Hall, 1977) added to the natural resources knowledge base of Pearl Harbor and included discussion of wetland resources. *AECOS* Inc., an environmental consulting firm, has been active in the Pearl Harbor area for over 20 years, preparing environmental reports which have covered specific wetland and stream resources in the area (*AECOS*, 1986, 1988b, 1994, 1996, 1999, 2000, 2001a, 2001b, 2002a, 2005). A bibliography of pertinent references is provided at the end of this Introduction.

Significant in terms of its completeness as an inventory of the flora and fauna of aquatic environments around Pearl Harbor is the Pearl Harbor Biodiversity Project funded by the U.S. Navy. The two phases of this project covered investigations of marine organisms (Phase I, 1995-1997, Coles et al., 1997, 1999) and estuarine and freshwater organisms from the mouths of streams discharging into the harbor (Phase II, 1997-1998, Englund et al., 2000). In the present report we only utilize sampling location descriptions as applicable to wetland features, and do not provide biota results from the biodiversity project reports.

Wetlands Classification

The most straight-forward definitions of "wetland" are those similarly expressed by Cowardin, et al. (1979): "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water" and Mitsch & Gosselink (1986): an environment "...at the interface between truly terrestrial ecosystems and truly aquatic systems making them different from each yet highly dependent on both." The Cowardin, et al. definition, used by U.S. Fish and Wildlife Service (USFWS), is part of a classification system developed for wetlands and deep water habitats of the United States. A somewhat more restricted definition[2] is that issued jointly by the U.S. Army Corps of Engineers (ACOE; Federal Register, 1982) and the Environmental Protection Agency (EPA; Federal Register, 1980):

> wetlands are "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that

[2] USFWS definition is broader in scope for the reason that it is part of a classification system of aquatic habitats that includes wetlands. Although possibly in rare cases within the Pearl Harbor area the USFWS definition would apply to a habitat not regarded as jurisdictional and subject to EPA and ACOE authority, in the vast majority if not all of cases, habitats classified by USFWS (Cowardin, et al;. 1979) would be jurisdictional for the reason that federal jurisdiction pertains to "waters of the U.S." (Federal Register, 1982) which include many other aquatic habitats in addition to just wetlands as defined by ACOE (1987).

> under normal circumstances do support, a prevalence of vegetation typically adapted to life in saturated soil conditions.

The ACOE manual (1987, p. 14-15) for delineating wetlands amplifies on the definition above, but also briefly covers definitions, diagnostic characteristics, and technical approach for the identification and delineation of deepwater aquatic habitats and non-wetlands. Although the ACOE manual serves as the technical basis for delineating wetlands (by which is meant establishing a jurisdictional boundary defining a wetland's limits), it does not provide a classification of wetlands. The USFWS system presented in Cowardin, et al. (1979) classifies wetlands and other aquatic habitats, and is therefore of considerable value in a general inventory such as presented in this report.

Aquatic Environment Classification ~ The USFWS classification system is hierarchical, at the highest level consisting of five "systems" (Cowardin, et al., 1979, p. 5): Marine, Estuarine, Riverine, Lacustrine, and Palustrine.

The **Marine System** pertains to intertidal and subtidal aquatic habitat off the ocean shore. In the area covered by the present survey, this would only be shoreline and fringing reef habitats outside of the mouth of Pearl Harbor (see Chapters 1 and 6).

The **Estuarine System** in the USFWS classification covers deepwater tidal and adjacent tidal wetlands within a basin semi-enclosed by land and having marine water that is at least occasionally diluted by freshwater runoff. This definition would apply to Pearl Harbor itself.

The **Riverine System** includes all wetlands and deepwater habitats confined to a channel, excluding 1) wetlands dominated by emergent vegetation and 2) habitats with ocean-derived salts in excess of 0.5 ppt.

The **Lacustrine System** encompasses lakes and ponds: aquatic environments confined in a natural or man-made basin and either lacking emergent aquatic vegetation or the vegetation is 30% or less of the area of the feature. The Lacustrine System includes all freshwater bodies of water over 20 ac (8 ha) in area, or smaller features if 1) all or part of the margin is an active wave-formed or bedrock shoreline, or 2) the deepest part of the basin exceeds 6.6 ft (2 m).

The **Palustrine System** covers vegetated aquatic environments developing in association with freshwater sources. In the USFWS classification (Cowardin, et al. 1979), these are fresh water wetlands (salinity less than 0.5 ppt) with emergent vegetation, but including open water areas 1) lacking vegetation if less than 20 ac (8 ha) in area, 2) lacking a bedrock or active wave-formed shoreline,

and 3) less than 6 ft (2m) deep in the deepest part. Thus, most freshwater ponds in the Pearl Harbor area would be included in the palustrine system.

National Wetland Inventory ~ The National Wetland Inventory (NWI) covering areas of Pearl Harbor was very recently updated (mid-2007) using EatrthData 2005 imagery (Elaine Blok, USFWS, pers. comm). The previous inventory coincided with the ACOE (1999) survey of wetlands in the area. The 1999 update process utilized aerial photographs dated September 1992 and included field work conducted in 1998-99 (Helber Hastert & Fee, 2001). The most recent update was undertaken in early 2007 with revisions to the wetland maps appearing on-line in late July 2007 (USFWS, 2007). Methodology and summary data have yet to be reported.

The NWI utilizes the system of classification developed by Cowardin et al. (1979) described above and includes wetlands and other jurisdictional waters—that is, not just vegetated wetlands as defined by the Army Corps (ACOE, 1987). Thus, all waters (estuaries and tidal waters) in Pearl Harbor are classified in the NWI system maintained by the USFWS, including the permanently submerged waters of the lochs and all tidally influenced areas along the shore. The statement in Helber Hastert & Fee (2001) that "[b]ecause of the [USFWS] more liberal definition of wetland....the NWI maps include areas that are not considered 'jurisdictional' wetlands subject to federal laws and regulations" is not entirely true. Deep waters and tidal lands (and streams) are jurisdictional in the same sense that ACOE certified wetlands are jurisdictional.

The NWI maps (URL: http://wetlandsfws.er.usgs.gov/wtlnds/launch.html) are a valuable source of information about the occurrence of wetlands in different areas, so the 1999 maps (later compared with the 2007 maps) were regularly consulted to locate wetlands around Pearl Harbor. Our experiences in this regard are discussed throughout the text of the report, including suggestions for classification using the Cowardin system where reclassification is indicated by our field observations[3]. The last NWI Wetland classification summary is provided here as Table 1 from the Pearl Harbor INRMP. Note that the large area of "permanently flooded estuarine wetland" reflects the fact that in the Cowardin system, all Pearl Harbor subtidal waters are counted, whereas vegetated, intertidal areas (e.g., mangrove) are mostly in the "other" category.

[3] Our experience after visiting nearly all of the sites around Pearl Harbor is that many if not most were assigned incorrect classification codes in 1999, These shortcomings have been corrected in many cases in the latest (2007) version, although we still disagree with many code assignments made in 2007. In the text, we provide the 2007 NWI code assignments and, where we disagree, our suggested code assignments for each wetland feature discussed. The coding scheme from USFWS is presented as Appendix A following the References Cited in this report.

Presently, no updated accounting based on the 2007 NWI mapping effort is available from USFWS.

Table 1. NWI Wetland classification of Pearl Harbor
(after Greenhorne & O'Mara, 1999)

Wetland Type	Area (acres)	Area (hectares)
Estuarine		
Permanently flooded	4,758.5	1,925.7
Other	367.8	148.8
Palustrine	72.9	29.5
Riverine	8.1	3.3
Total	**5,207.3**	**2,107.3**

The ACOE (1999) summary of wetlands in Pearl Harbor from their field and mapping efforts concluded there were 456.41 ac (184.7 ha) of wetlands, classifiable as 288.40 ac (116.7 ha) of mangrove wetlands, 81.99 ac (33.2 ha) of "other coastal" wetlands, 13.77 ac (5.6 ha) of "stream" wetlands, and 72.25 ac (29.2 ha) of "other freshwater" wetlands. With respect to freshwater aquatic features (palustrine and riverine systems), the NWI and ACOE accountings are similar.

Pearl Harbor Wetlands

The formation of Pearl Harbor—how it came to be in its present day configuration viewed over geological time—is complex but well covered in various texts (see Stearns, 1966; MacDonald et al., 1983; drawings in ACOE, 1999 after Stearns) and need not be repeated here. While events over hundreds of thousands of years established the general lay of the land, wetlands extant along and behind the modern shore are much more recently formed and owe their existence to several basic features of the Pearl Harbor basin. One is the "great Pearl Harbor springs, with a discharge of almost 230 million liters per day (earlier in the [last] century discharge averaged about 300 million liters per day)..." (MacDonald et al., 1983, p. 236). These springs issue directly from Koʻolau lava rock not far inland from the shore (Fig. 1) and have been regarded as the largest and most significant complex of springs in the Hawaiian Islands, contributing some 70% of the fresh water flowing into Pearl Harbor (Englund, et al., 2000).

Pearl Harbor is a large estuarine feature on the south coast of the Island of Oʻahu fed by several streams and numerous freshwater springs. The basin represents drowned valleys that now comprise the lochs and is somewhat unusual in the convergence of these broad shallow valleys into a single, narrow

outlet (most valley or fluvial features tend to broaden downslope). It has been said that the "...Pearl Harbor spring, coastal wetland, and riverine systems represent an ecologically important and unique natural resource and formerly contained a significant endemic fish and invertebrate fauna" (Titcomb, 1972 cited in Englund et al., 2000). These areas are now dominated by introduced species. Excluding terrestrial arthropods found in riparian areas (also surveyed), 192 aquatic species have now been identified in the lower reaches of Pearl Harbor streams and wetlands. Introduced species were 47% of the species recorded, while only 33% were native (endemic or indigenous) and the balance (20%) undetermined (Englund et al., 2000).

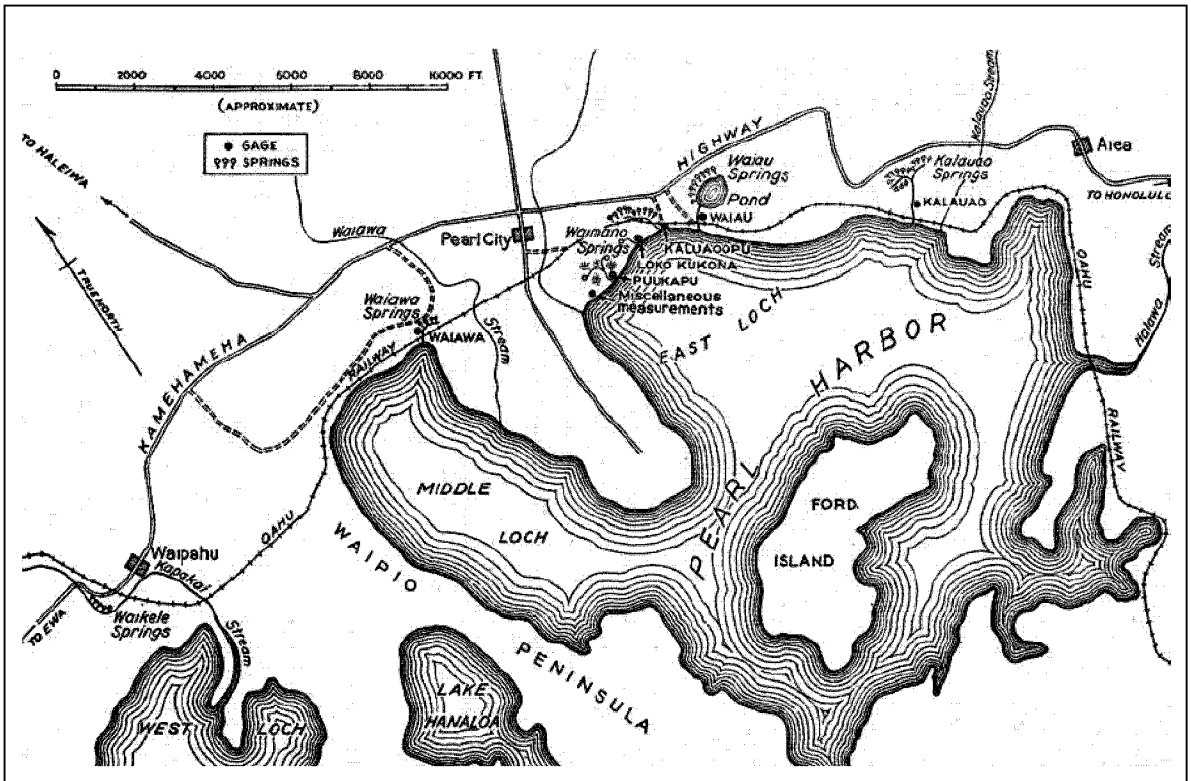

Figure 1. Historic map of the major Pearl Harbor springs in 1935 (after Stearns and Vasvik, 1935 from Englund et al, 2000).

Estuarine Wetlands ~ Prior to use of the "harbor" as a military asset, the original basin of Pearl Harbor was quite shallow throughout and the shoreline lined by Hawaiian fishponds (and prior to the arrival of the early Polynesians, probably lined by extensive wetlands). Dredging for harbor development greatly altered the bathymetry and must have likewise changed the relationship between land runoff and tidal exchange, causing the entire feature to become less brackish and more saline. Consequently, many former wetlands that were inhabited by native marsh vegetation tolerant of some saltiness (plants such as *makai* and *kaluhā*) found the increasingly marine nature of the shallows

unsuitable and subsequently disappeared. Exposed barren tidal flats and abandoned fishponds provided habitat for species of introduced plants, two of which have become especially prominent: pickleweed (*Batis maritima*; see page 17) and American or red mangrove (*Rhizophora mangle*; see page 14)[4]. The requirements of these two species now define the extent of coastal or saline vegetated wetlands in Pearl Harbor (as well as in many other locations in the Islands, such as Kāne'ohe Bay and much of the south shore of Moloka'i).

So prominent are pickleweed and mangrove in the coastal wetlands of Pearl Harbor, that only the physical nature of the shoreline itself influences which type of wetland will be present in any given location: an *'ākulikuli kai* (Hawaiian name for *Batis maritima*) tidal flat or a mangrove swamp. In as much as propagules generated by the abundant mangrove trees reach all tidal shoreline areas, only physical factors that tend to discourage establishment of young mangroves determine the eventual fate of progressive vegetation development. As with any tidal shore, there are sections of generally low slope and sediment deposition and sections of steeper banks of rock or other hard material (such as concrete). Modifications to the shore and nearshore—dredging, placement of revetments and other structures—influence the physiography of the shore, as has occurred in most areas of Pearl Harbor, beginning with the ancient Hawaiians constructing rock walls to define fishponds. Another influencing factor is the discharge of sediments from upland drainages, a process that was greatly accelerated with the coming of western-style agriculture (sugar cane and pineapple) and a likely reduction in the freshwater flux as upland streams and lowland springs were tapped to service the agricultural fields (the first artesian well developed in Hawai'i was drilled at Hono'uli'uli in 1879; MacDonald, Abbott, and Peterson, 1983). The point to be made is that the very nature of Pearl Harbor has changed significantly over the last century and a half and the introduction of various "aggressive" alien plants is only part of the story. These plants are viewed as aggressive because they easily out-compete other (native) plants for physical space, but the advantages they have in this competition are more than genetic; more than the simple sum of characteristics they possess. The very nature of the physical environment changed, a circumstance that placed the native inhabitants at a disadvantage, if not alone accounting for their demise.

[4] *Batis maritima* was first recorded at Sand Island by Hillebrand (1888) in 1859 and first noted present in Pearl Harbor by Hosaka (1937) in West Loch; however, Englund et al. (2000) displays a photograph on the cover showing pickleweed in the Harbor (Kukona Fishpond, Waiau) in 1911. *Rhizophora mangle* was first introduced on Molokai in 1902 (Degener, 1940) and noted in Pearl Harbor as early as 1917 (Wester, 1981).

The difference in nature of the shore and subsequent wetland development is clearly illustrated by the peninsula at West Loch Shoreline Park. This feature is a finger of lava rock that extends into West Loch. The dominant Trade winds, blowing from the northeast to east, set-up waves across the upper end of West Loch that erode the north shore of the peninsula (Fig. 2a). The south-facing shore is more sheltered and consequently, depositional. The gradual transition to deeper water across a shallow, low-sloping tidal flat or beach is one quite suitable for emergent plants tolerant of the salinity regime. Consequently, the south shore is one of wetlands vegetated either by *'akulikuli kai* or mangrove (Fig. 2b).

The following stages were described by Egler (1939) as representing typical succession of many Hawaiian intertidal flats: (1) original native communities of Widgeon Grass (*Ruppia maritima*), various species of algae, and sessile organisms, (2) introduction of Pickleweed (*Batis maritima*) and subsequent development of pure meadows, (3) introduction and spread of Red Mangrove (*Rhizophora mangle*), (4) extirpation of indigenous *Hau* (*Hibiscus tiliaceus*) forests by mangrove forests, and (5) the eventual displacement of pickleweed meadows by mangrove forests.

There can be no doubt that pickleweed and red mangrove compete with each other for space along much of the shoreline, having similar preference for shallow tide flats. Char (2000) noted recently that "...before the rapid expansion of mangrove, pickleweed was the most abundant vegetation type in the Pearl Harbor area (Char & Balakrishnan, 1979). She points out that in this competition, red mangrove typically succeeds in shading out low growing pickleweed shrubs, and dominates an area pretty much to the exclusion of all other plant species. It may not be the case that all areas presently dominated by pickleweed will eventually succession into mangrove forest. Experience at Nu'upia Ponds (AECOS, 1985b) on the Mōkapu Peninsula (windward O'ahu) demonstrates that pickleweed has a greater tolerance for hyperhaline conditions where mangrove either cannot establish or clearly struggle once established. Further, pickleweed grows in the upper intertidal and, in some cases, out onto adjacent uplands or semi-isolated basins where red mangrove cannot invade. These reasons may explain, in part, the observation by Char (2000) of pickleweed flats "squeezed inland by the advancing [mangrove] thickets."

Mangrove expansion in Pearl Harbor is largely seaward, leaving in some cases more open flats behind the original colonization "shore" that seasonal hyperhalinity or other factors prevent mangrove propagules from successfully establishing. Of course, caught behind a wall of mangrove, such flats may be relatively short-lived if subjected to sediment deposition from the land. Such

Figure 2: a) North side of peninsula at West Loch Community Park showing upland vegetation reaching to the exposed, basalt rock shore (no wetlands are present here). b) South side of peninsula showing mixed *'akulikuli kai*/red mangrove wetland across a gently sloped shore.

isolated flats, if subjected to regular inputs of freshwater have the potential for developing into palustrine wetlands, a few examples of which are found around Pearl Harbor. If the isolated depressions lack significant freshwater (as runoff, stream input, or groundwater), the proximity to haline waters of the harbor (with typically brackish groundwater) create salt flats supporting pickleweed and no or minimal mangrove growth. Accumulation of salts in the soil can reach a point where even pickleweed cannot continue to grow (Fig. 3; see also Fig. 3-05[5] and p. 17), and the central depression of these shallow basins will be barren of vegetation. This sets up a situation, known as a playa, where the soils (flocculated by salts) are easily moved by winds when dry, and the basin persists or enlarges as sediment is blown away during the dry season.

Figure 3. Playa formation beside the old Pearl City WWTP. Salt encrusted, bare soil in foreground is depressed relative to the flat behind overgrown with pickleweed, but the soil too salty to support even pickleweed.

Palustrine Wetlands ~ Palustrine wetlands are associated with sources of fresh water—around Pearl Harbor these would be the extensive springs that issue not far inland along the northern shores of the lochs. Palustrine wetlands also may be associated with streams. Riverine wetlands are rare or not present

[5] The reference to Fig. 3-05 means Figure 05 in Chapter 3 of this report.

in the survey area for the reason that definitions do not allow for them even though both the NWI (Greenhorne & O'Mara, 1999) and ACOE (1999) appear to conclude that there are some present—respectively, 8.1 and 13.8 ac (or 3.3 and 5.6 ha; see Table 1 and text following). By definition (Cowardin, et al., 1979), Riverine System habitats are characterized by freshwater and no emergent vegetation (that is, not wetlands by the ACOE definition). Larger streams flowing into Pearl Harbor are estuarine in the lower reaches, so the Riverine System would only apply to stream channels *upstream* of the estuaries. Stream associated wetlands registered by the ACOE (1999) study must be Palustrine Systems under the NWI definition. On the other hand, streams and even small drainage ditches draining uplands are classified as Riverine in the NWI (2007)—around Pearl Harbor, however, always upstream of a lowland, estuarine stream or ditch segment.

Coastal wetlands in Hawai'i have been subjected to substantial changes as a consequence of, among other factors, invasion by introduced mangrove and/or pickleweed. Although these plants are limited to tidal and estuarine waters, freshwater wetlands have also been impacted by introduced plant species, particularly the aggressive para grass (or California grass; *Urochloa mutica*). As well, both great bulrush (*Schoenoplectrus californicus*) and common cattail (*Typha latifolia*) are introduced species now widely distributed in palustrine wetlands around the islands. As a result of these invaders, the floristic structure of impacted wetlands has been altered, although the oft cited concept (e.g., Wilson and Loomis, 1967) that encroachment of vegetation results in terrestrialization, or an eventual shrinkage in wetland area, is not well supported by studies (Mitsch and Gosselink, 1986). If anything, open waters are gradually transformed into wetlands, which can remain as wetland bogs for centuries. Losses in wetland area are most likely the result of direct human interventions: adding fill material or altering hydrology by draining or diverting.

Invasion by California grass can alter the relative abundance of other wetland plants present, but the primary impact and the one of greatest concern is the gradual diminution of open water habitat utilized by waterbirds (Oceanit, 2006). Thus, this plant and several others (for example, water hyacinth, Kariba weed, and cattail; see AML, 2004) are not so much threats to "wetlands" as defined by the ACOE (1987) but to open ponds and bare mudflats that serve as important endangered species habitats in Hawai'i. In an ironic sense, by occupying wet areas previously not supportive of native emergent vegetation, these invasive plants actually increase the area occupied by ACOE defined wetlands.

ACOE Wetland Designations ~ Various systems are in use for designating or indicating a particular wetland. Preferred, for common acceptance and general ease of use, are place names. However, for small features or wetlands

that are perhaps only a small part of a larger named feature, place names may not be all that helpful. In the ACOE (1999) report on the wetlands of Pearl Harbor, a ten digit number was assigned to each wetland feature. In as much as this report is an update of that 1999 report, it is desirable to retain the Corps' numbering system if for no other reason than to provide a means of cross-referencing the wetland descriptions. Although the 1999 report does not much utilize wetland ID numbers in the text, the maps that were developed do. The attributes of the ten digit number are explained this way in the metadata table provided (punctuation added):

> A numbering system developed by the Corps and used to uniquely identify wetlands in the Hawaiian Islands. Each wetland is given a ten digit number (ABCDEFGHIJ); digits CDE represent a specific wetland delineation project; digits FG represent subprojects or segments within a project; digits HIJ is a numerical number assigned to a specific wetland for a specific segment within a specific project.

Although digit pair "AB" is not explained, presumably it could represent the island or part of an island within the Hawaiian chain. For all of the wetlands described in the ACOE report, this value is 21; the specific project descriptor is always 001. The "FG" code appears to represent the segment of Pearl Harbor shore (varies from 01 to 12). Thus, only these last 5 digits ("FGHIJ") are needed to uniquely designate a place within the scope of this project. For the reason that a few digits is much easier to read than a 10-digit number, we represent the ACOE system throughout our text as follows:

..3165 is 2100103165 (larger of the Honouliuli Unit ponds at Pearl Harbor National Wildlife Refuge or PHNWR)

.12007 is 2100112007 (a subsegment of the shore of Ford Island; not used in the ACOE text, but may appear in the 1999 data base; not used in this report)

Note first that the segment ("3" in the first sample above) refers to the 1999 system and not the segments utilized herein (which we define as chapters in our text). ACOE segments beyond 9 require addition of another digit in our simplified presentation, but these are segments on the east side of Pearl Harbor and on Ford Island where there are no wetlands (see Chapter 6).

Although we have adopted the numbering system developed by the ACOE for their 1999 survey and use it extensively throughout the text, it must be noted that in many cases the reason for subdividing a wetland are obscure to us; they possibly served an accounting function of some use to the 1999 survey. The result is that there are a good deal more uniquely numbered wetlands than

seems necessary, while wetlands that were missed or parts of wetlands that truly are ecologically distinct from adjacent but not uniquely numbered areas have had to be assigned numbers by us. Where new numbers are needed, we have assigned unused numbers from series representing nearby wetlands.

Wetland Delineation

"Wetland delineation" refers to the process of establishing a wetland boundary, usually for legal purposes, utilizing methodologies described in the *Corps of Engineers Wetlands Delineation Manual* (also herein as "the manual"; ACOE, 1987). A wetland boundary separates a wetland (as defined by EPA/ACOE) from non-wetlands: uplands and deep water habitats. In all cases, it is the boundary between wetland and upland that is of greatest interest. The boundary between wetland and deep water habitats is, from the perspective of the ACOE manual, the outer edge of emergent vegetation.[6] Obviously, for open waters within a wetland, there is some minimal size that would be considered simply part of the wetland and not "deepwater aquatic habitat", but this minimal size is not defined in the manual. In the USFWS system (Cowardin et al., 1979) open waters of over 20 ac (8 ha) are classified in the Lacustrine System; but smaller ponds are lacustrine only if certain other physical conditions pertain (see p. 3 above).

The manual allows for considerable flexibility in methodology for establishing a boundary between wetland and upland, but requires that in most cases all three of the following must be present on the wetland side: 1) hydrology (i.e., water or a source of water), 2) wetland vegetation (an assemblage of plant species indicative of wetland conditions), and 3) wetland soil (a defined hydric soil type or certain redoximorphic properties indicative of inundation). Moving outward, a bounding point for the wetland becomes that point where any one of these characteristics ceases to be present. It is generally sufficient to establish that a feature is a wetland as defined by the manual, understand what specific characteristics provide field evidence of the bounding line, and delineate along that line. In conducting an inventory, it is far too time consuming to establish bounding points by sampling vegetation and soil at multiple places inside and outside of a suspected wetland. Field observation and marking on good aerial photograph can be used to delineate a wetland for inventory purposes, while a more careful placement of the line would be needed where a project in the design phase requires fairly precise mapping to either avoid or establish and quantify wetland encroachment. In the latter case, it is standard practice to

[6] Technically, deepwater aquatic habitats have at least one of the following: 1) permanently inundated and lacking rooted, emergent vegetation, 2) bottom a sediment not a soil and does not support rooted emergent or woody plants, or 3) permanently inundated at depths >6.6 ft (2 m).

place stakes or flags along the delineated boundary and have these located by land survey.

In the present case, it seemed clear that the ACOE inventory in 1999 (ACOE, 1999) was essentially an inventory approach, and we have followed in that same vein. Satellite images and field or ground-truthing were combined to establish probable wetland boundaries. Attempts to utilize a GPS unit in the field to create a shape file representative of a wetland boundary were generally frustrated by poor or no reception in densely forested areas (either at the edge of the mangrove or in an adjacent upland *kiawe* forest). Further, it was not practical to plot the outer, open water edge by GPS either, and both boundaries are clearly evident in the photographs anyway. The resulting shape files created from photographs and field notes, superimposed on the satellite images, are incorporated in this report as an attachment at the end.

We deviate in one respect that bears mentioning, although in truth the impact on results is nil for Pearl Harbor wetlands. The manual requires that wetland status of plants be obtained from a specific source, namely Reed (1988). However, that source is out of date and a better (although unofficial) source is that of Puttock and Imada (2004), which we use in this report.

Regulatory Issues ~ Since 1999, two Supreme Court decisions—*Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, widely known as the SWANCC case and *Rapanos v. United States*—have thrown into question the interpretations by EPA and ACOE of Clean Water Act jurisdiction or coverage (ELI, 2007). The resulting shift and uncertainty in regulatory authority complicates the delineation process, although again the impact on Navy wetlands in and around Pearl Harbor is not substantive. Clarification of ACOE policy in light of the Supreme Court decisions is now available (ACOE, 2007, EPA/ACOE, 2007).

At the center of Clean Water Act issues (CWA, Section 404) are interpretation of the term "waters of the United States" (33 CFR § 1362(7)) from which flows the regulatory authority of both EPA (40 CFR Part) and ACOE (33 CFR Part 38). Thus, "waters of the U.S." are also called "jurisdictional waters." It is possible to utilize any wetland definition to map an area as a wetland. The National Wetland Inventory (NWI) follows USFWS definitions for this purpose. For CWA purposes, the ACOE manual (ACOE, 1987) applies, but if the feature is not "waters of the United States," ACOE jurisdiction does not apply. The distinction between wetlands and "waters of the U.S." is important for another reason: many more aquatic environments are jurisdictional than just those delineated as wetlands. And this distinction applies two different ways: 1) a delineated boundary typically divides wetland from upland or at least from non-wetland;

and 2) aquatic features that fail to satisfy the requirement of a wetland by the ACOE definition, might still be jurisdictional.

In all cases discussed in this report, ultimate authority for establishing jurisdiction over a particular feature rests with the Army (ACOE), not with the preparers of this text. However, at least since *SWANCC* (2001) and *Rapanos* (2006), ACOE authority over wetlands and other waters previously claimed as jurisdictional under CWA has been reduced. Because ACOE jurisdictional authority is in flux, we have retained, in our descriptive chapters, all previously inventoried wetland features (ACOE, 1999; USFWS, 1999). While presenting our position on the likely regulatory status of all these aquatic features, we have provided descriptions and some level of mapping, whether jurisdictional or not, as a conservative approach.

Table 2 summarizes the current policies of the Army Corps in establishing jurisdiction over various aquatic features. *Traditional Navigable Waters* are "[a]ll waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide." (33 CFR § 328.3(a)(1); 40 CFR § 230.3(s)(1).

Note that where the Corps must decide jurisdiction based upon a "significant nexus with traditional navigable water," the process can become very involved.

The state of Hawai'i regulates state waters, which are defined as "all waters, fresh, brackish, or salt around and within the State, including, but not limited to, coastal waters, streams, rivers, drainage ditches, ponds, reservoirs, canals, ground waters, and lakes ... including wetlands." Wetlands are defined by the state using the ACOE manual (see HAR §11-54-1).

The primary regulations the state of Hawai'i uses to protect wetlands is the CWA Section 401 permitting program. Section 401 requires that applicants for a federal permit also receive a Water Quality Certification (WQC) that indicates that the proposed project will not violate local water quality standards. If a federal permit is not required (for example, a project does not involve jurisdictional waters), then a Hawai'i WQC is not required. However, the Department of Health - Clean Water Branch (HDOH-CWB) has the authority to protect existing uses and the level of water quality under the water quality antidegradation policy (HAR §11-54-1.1). The antidegradation policy applies to all waters (including wetlands) in Hawai'i, whether or not they fall under federal jurisdiction.

Table 2. Summary of Key Points (from EPA/ACOE, 2007)

The agencies will assert jurisdiction over the following waters:

- **Traditional navigable waters**
- **Wetlands adjacent to traditional navigable waters**
- **Non-navigable tributaries of traditional navigable waters that are relatively permanent where the tributaries typically flow year-round or have continuous flow at least seasonally (e.g., typically three months)**
- **Wetlands that directly abut such tributaries**

The agencies will decide jurisdiction over the following waters based on a fact-specific analysis to determine whether they have a significant nexus with a traditional navigable water:

- **Non-navigable tributaries that are not relatively permanent**
- **Wetlands adjacent to non-navigable tributaries that are not relatively permanent**
- **Wetlands adjacent to but that do not directly abut a relatively permanent non-navigable tributary**

The agencies generally will not assert jurisdiction over the following features:

- **Swales or erosional features (e.g., gullies, small washes characterized by low volume, infrequent, or short duration flow)**
- **Ditches (including roadside ditches) excavated wholly in and draining only uplands and that do not carry a relatively permanent flow of water**

The agencies will apply the significant nexus standard as follows:

- **A significant nexus analysis will assess the flow characteristics and functions of the tributary itself and the functions performed by all wetlands adjacent to the tributary to determine if they significantly affect the chemical, physical and biological integrity of downstream traditional navigable waters**
- **Significant nexus includes consideration of hydrologic and ecologic factors**

Note: "Agencies" refers to U.S. Army Corps of Engineers (ACOE) and U.S. Environmental Protection Agency (EPA).

Mangrove wetlands ~ The following is taken from AECOS (2006, p. 12):

> Mangrove ecosystems, or mangals, are a type of coastal wetland, defined in the National Wetlands Inventory (Cowardin et al., 1979) as haline estuarine intertidal forested and shrub wetland. Wetlands are among the most important ecosystems on Earth (Mitsch and Gosselink, 1993), are protected by international treaties as well as federal law (Clean Water Act), and are managed in the US under a "no net loss" policy. Throughout their natural distribution, mangals provide coastal shoreline protection, reduce nearshore water pollution, provide a forestry and fishery resource, and act as a refuge for wildlife. Even in Hawai'i, mangrove forests may benefit the marine environment by providing habitat for many animal species (many non-native), removing and sequestering dissolved nutrients from water, and holding back sediments derived [from] land run-off.

The red mangrove (*Rhizophora mangle*) is an obligate wetland plant (Reed, 1988; Puttock and Imada, 2003) from tropical America, described as aggressive-invasive in Erickson & Puttock (2006). Although there are two species of mangrove established in Hawai'i, only *R. mangal* is widespread. The other species (*Bruguiera sexangula*) is uncommon and found only on O'ahu (Erickson & Puttock, 2006). No occurrences of *B. sexangula* were noted during our surveys (nor was it reported in ACOE, 1999), but differentiating this species from *R. mangal* does require paying careful attention to each tree (*B. sexangula* has knee roots and lacks the prop roots of *R. mangal*; Fig. 4), so distribution of *Bruguiera* in Pearl Harbor remains unknown to us.

Figure 4. Red mangrove growing along a creek in Wai'au. This view from beneath the canopy shows the extensive prop-root growth of youthful trees. Note numerous mangrove seedlings on opposite bank.

Although an obligate wetland species, it is not clear that any growth of mangrove along the shore of Pearl Harbor, even though assigned a wetland identification number by ACOE (1999), is actually wetland. Soils may be presumed hydric, but are not necessarily present in many situations. To wit, (ACOE, 1999, p. 49): "...mangroves of themselves do not constitute a regulatory wetland." Mangroves occur in waters of the U.S., but sometimes in situations

which are not wetlands: on rock and coarse sand and gravel shorelines, and the banks of streams and other channels wherever seedlings are carried and take root. As pointed out in their 1999 report, once "...there is a buildup of sediment caused by mangrove encroachment, the stream or shoreline may change from a waterway to a wetland." Much like the difficulty of differentiating a small pond from an open water part of a wetland, there is no sharp point at which an area of mangrove growth becomes a wetland by this approach. The manual (ACOE, 1987, p. 54) allows that if the dominant vegetation has an indicator status of obligate, the soil (or sediment) is presumed to be hydric requiring no further inspection. It is mute on the point of whether there must be a soil or sediment present. Mangroves are not just dominant species where they grow, but typically the only vegetation present of any consequence (see Fig. 4), an exception sometimes being pickleweed (see p. 20), also an obligate wetland species.

In this report, we have generally tried to describe as "mangal"—a term meaning a mangrove forest—areas of mangrove growth that clearly are wetlands. These are stands of several to many trees in all directions with a buildup of organic-rich soil/sediment on the forest floor (see *AECOS*, 2006 for a practical example differentiating mangroves from mangal in Kāne'ohe Bay). We are more circumspect about the many narrow but in some places continuous bands of mangrove shrubs along rocky shores, gravel beaches (Fig. 5), or man-made estuarine channels in Pearl Harbor. It is evident from the text that the Corps delineators in 1999 were aware of such a distinction, although were conservative on the side of designating more such growths as wetlands than might stand to careful scrutiny. The most recent version of the NWI (USFWS, 2007) appears to define all occurrences of mangrove as wetlands under the Cowardin classification system (see p. 3, above), in some cases apparently differentiating between mangroves growing as shrubs and mangroves growing as trees, although we are unable to find any consistency in the application of one code over another.

We suggest that the classification of mangrove dominated habitat following Cowardin et al. (1979)[7] is E2FO3N: estuarine intertidal broad-leaved evergreen forested, regularly flooded wetland. Where mangrove growth is sparse and the plants are shrubs less than 6 m in height, the NWI coding could be E2SS3N: estuarine intertidal broad-leaved evergreen scrub-shrub, regularly flooded wetland. Such areas are usually not counted by us as wetlands and the same

[7] Cowardin, et al. (1979) does not actually provide the codes used by the NWI, These were developed later and have been subject to additions/modifications over time. Our Appendix A summarizes the coding as presently provided by the NWI website.

coding might apply to intertidal pickleweed flats (a shrub; see p. 20). Any area identified as a mangal by our definition would be coded, E2FO3N.

Figure 5. Red mangrove establishing on a gravel beach shoreline presently occupied above by pickleweed that will, over time, be overgrown or isolated behind a mangal (*AECOS*, 2006).

Almost without exception, any area of mangrove growth in Pearl Harbor is jurisdictional, whether a "wetland" as defined by ACOE (1987) or not. Consequently, we have not shown as wetlands on our delineation maps what appear to us to be isolated growths of red mangrove and not mangal, or channels and other soft-sediment sites where mangrove has been recently removed. In the latter case, this is not to imply that the site was wetland and is now not wetland simply as a result of removal of the wetland indicator plant. The manual describes methods for delineating wetlands where the vegetation has been altered by recent human activity. In all cases, these locations have reverted (or presumably will) to either mudflat (a special aquatic site) or unvegetated tidal channel. Whether maintenance is planned to keep them

mangrove free or mangroves do recolonize, our pragmatic view is that at the time of this survey they were no different than shallow tidal waters that have yet to be covered by mangrove growth, identical in status to a shrinking central pond (non-wetland) of a former Hawaiian fishpond gradually being overgrown by mangrove.

Delineations of mangal in our survey have been accomplished mostly by using aerial photographs in the field to "establish" the wetland boundary. In most cases, mangrove trees can be easily distinguished in satellite images. This approach has proven necessary because GPS equipment provides generally low accuracy (or no reading) for positions under the dense canopy of the mangal, and as well under the canopy of *kiawe*, a typical vegetation type of the upland bordering a mangal.

Because mangrove in Hawai'i is "a landscape-altering species' (Erickson & Puttock, 2006, p. 128), local ACOE policy with respect to permits is to support removal of alien mangrove in the Hawaiian Islands, a sensible approach because a mangrove-denuded area may cease to be a wetland by definition but does not lose its status as jurisdictional waters of the U.S. A surprising amount of mangal—well-established mangrove forest—and isolated mangrove shrubs were removed from Pearl Harbor shores during the period of our field efforts (September 2006 to July 2007).

Pickleweed wetlands ~ Pickleweed or *'ākulikuli kai* (*Batis maritima*) is a small maritime shrub, one of only two species in the genus and in the Family Bataceae. *B. maritima* was first noted growing in a salt marsh at what is now Sand Island on O'ahu by Hillebrand in 1859 (Wagner et al., 1990). The species is native to the Americas.

The common name refers to organs resembling small pickles in which the young flowers are initially enclosed. Pickleweed is listed as an obligate wetland species in both Reed (1988) and Puttock and Imada (2004), and its growth is pretty much restricted to marine and estuarine upper shorelines areas. It is described as aggressive-invasive in Erickson & Puttock (2006). On the lower shore, pickleweed is limited by lack of tolerance to lengthy immersion, therefore advancing only just into the upper intertidal. On the upper shore or inland along estuaries, pickleweed is also limited to saline conditions, and its presence can be used to infer saline influence beyond that afforded by brackish water. The grass, *Paspalum virginicum*, usually replaces pickleweed where conditions are not quite saline enough for the latter.

Pickleweed is an excellent indicator of isolated or semi-isolated saline wetlands (Fig. 6) and thus a potential indicator of the reach of the highest tides, the latter

being an important jurisdictional marker. Because pickleweed can exhibit scrambling growth, the upper edge of the plants is not necessarily at the extreme of either tidal reach or wetland conditions. In drier parts of the island, a saline tidal flat may have, along its border, a significant incursion of perhaps several meters by pickleweed into the surrounding upland. Further, the plant will not tolerate salinity extremes of evaporative saline basins. The lowest part of such basins (where the most salts are deposited) can be barren of all vegetation (Fig. 3, above), although are part of the wetland and likely tidal but irregularly flooded.

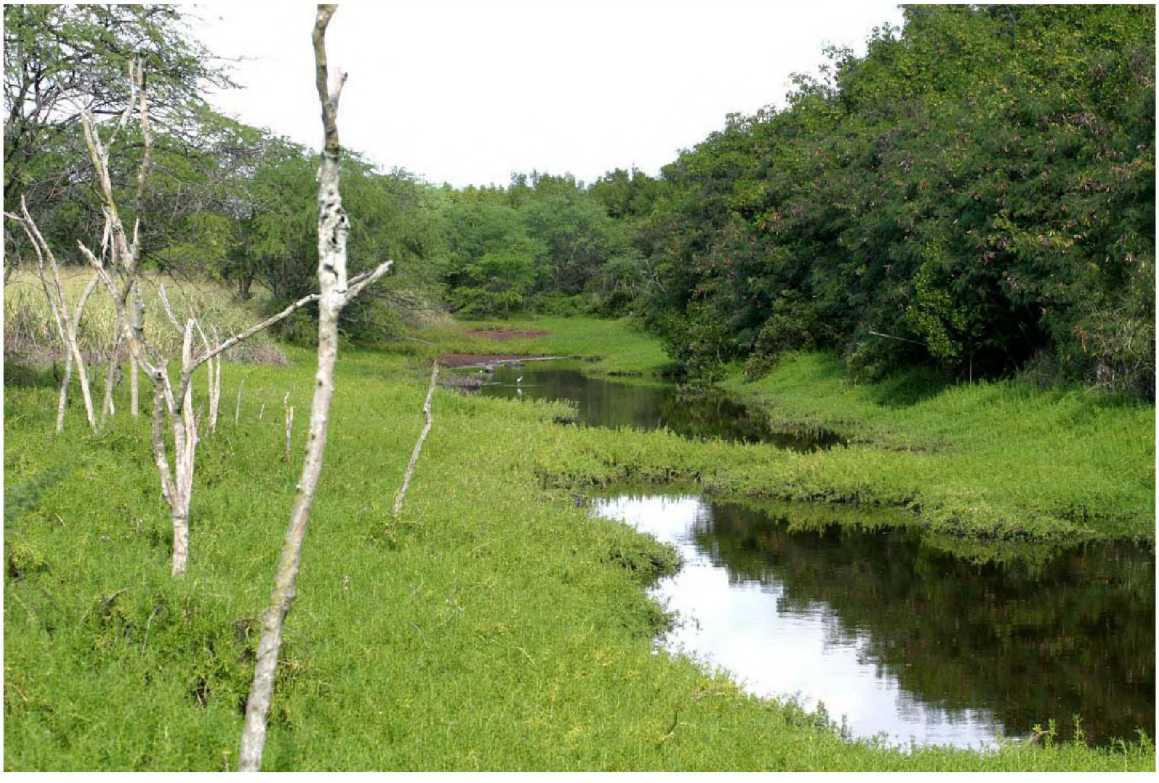

Figure 6. Pickleweed dominating a saline channel on the Pearl City Peninsula near the old Pearl City WWTP.

Pickleweed establishes along the shore in areas of quiet waters, especially where the substratum is sediment. This plant could dominate most of the Pearl Harbor shore, but for its intolerance of deep shade. Once mangrove becomes established on the same shore, the pickleweed is gradually edged out by the much taller growth of the mangrove (Fig. 7; see also Figs. 5 and 2b, above). Mangrove propagules initially establish in slightly deeper water, running out in front of the pickleweed shore. This sometimes results in a mangal with a

pocket of pickleweed along the landward edge where an irregularly flooded basin exists.

Figure 7. An interior area of pickleweed, south of West Loch Community Park, being slowly invaded by American mangrove (scattered shrubs on left and solid tree growth on right and background).

We suggest that the best classification of pickleweed dominated habitat using Cowardin et al. (1979) is E2SS3P: estuarine intertidal broad-leaved evergreen scrub-shrub, irregularly flooded wetland. Of course, some areas of pickleweed may be regularly flooded (E2SS3N). By definition (Cowardin, et al., 1979, p. 29), *irregularly flooded* pertains to "tidal water [that] floods the land surface less often than daily." However, the distinction between "daily" and "less often than daily" is difficult to make at the upper end of the intertidal zone where (as in the Hawaiian Islands) the tides are mixed semidiurnal and have a spring/neap tide cycle. The distinction between regularly and irregularly flooded cannot be made based on aerial photographs, requiring that either careful observations be made within the vegetation type over time or stadial surveys be conducted across the area. Irregular flooding intervals would be those limited to certain spring tides, spring tides at certain times of the year, or tides in concert with high groundwater levels, as in the wet season.

California grass wetlands ~ California or Para grass (*Urochloa mutica*; synonyms: *Brachiaria mutica* and *Panicum muticum*) is a sprawling perennial herb (grass) with stems that can reach 6 m (18 ft) in length. The native origin of this plant is unknown (tropical Africa is suggested in Erickson & Puttock, 2006), but it was first recorded on O'ahu in 1924 (Wagner, et al., 1990). It grows in areas of high soil moisture and is listed as facultative wetland (FACW) in Reed (1988) and Puttock and Imada (2004). On the wetter windward sides of the island, its presence is not a certain indication of a wetland, but on the drier leeward coast, its presence nearly always merits investigation for potential wetland conditions.

Figure 8. A somewhat unusual situation of a palustrine wetland dominated by California grass (foreground), the grass growing up into red mangrove at a palustrine/estuarine boundary.

California grass is particularly important in wetland ecology on O'ahu for the reason that its rapid growth after establishment can result in the loss of native wetland vegetation and open water areas important to waterfowl. The plant does not grow in deep water (or very well in shallow water for that matter), and may be limited in that regard, but its long, sprawling stems grow out over the water surface, advancing across each season's accumulation of dead stems to form a

thick, floating mat that eventually obscures the open water. Even large ponds, if not flushed by seasonal freshets, can be covered in a few years. This species is described as aggressive-invasive by Erickson & Puttock (2006) and is a potent threat to all palustrine systems around Pearl Harbor.

California grass grows within a range of situations, some neither wetland nor aquatic environment of any kind. We suggest that the classification of a California grass dominated wetland using Cowardin et al. (1979) is PEM1C: palustrine emergent herbaceous vegetation, seasonally flooded wetland or PEM1H if in an area permanently flooded (where California grass is overgrowing from the margins).

Abbreviations

Although most abbreviations are explained where first introduced in the text, this report is intended as a reference document that might not be read from front to back. The following abbreviations may be encountered without explanation:

ACOE - U.S. Army Corps of Engineers
AECOS - Not an acronym; *AECOS*, Inc.
DA - Department of the Army (as in DA Permit No...., an ACOE permit).
DLNR - Department of Land and Natural Resources (state agency)
DO - Dissolved oxygen; also DO Sat: the percentage of oxygen dissolved in water relative to the maximum theoretical amount given the salinity and temperature of the water.
C&C - City and County of Honolulu.
CFR - Code of Federal Regulations.
E - First order (system) NWI code for estuarine (see Cowardin et al., 1979).
HECO - Hawaiian Electric Company
ID - ACOE (1999) wetland surveys numbering system; in this report the given 4-digit number should be preceded by 210010 to yield the complete ACOE (1999) reference.
INRMP - Integrated Natural Resources Management Plan
M - First order (system) NWI code for marine (see Cowardin et al., 1979).
NAVMAG - Naval Magazine
NWI - National Wetlands Inventory (USFWS).
NWR - National Wildlife Refuge.
OR&L - Oahu Railroad and Land Co.; historical entity.
P - First order (system) NWI code for palustrine (see Cowardin et al., 1979); a freshwater wetland.
PACNAVFACENGCOM - Pacific Naval Facilities Engineering Command (NAVFAC Pacific).
PH - Pearl Harbor
PHNWR - Pearl Harbor National Wetland Refuge.
pH - Unit of measure of the acidity of a water sample.
R - First order (system) NWI code for riverine (see Cowardin et al., 1979).
USFWS - U.S. Fish and Wildlife Service (federal agency).
USGS - U.S. Geological Service (federal agency).

Hawaiian Words

A number of Hawaiian words are used widely in common speech and technical writing in the Hawaiian Islands (including common names of many plants). These words appear in italics in the text and are defined here. Hawaiian place names are place names and not italicized or explained further (with one exception in the list below).

ʻaeʻae - *Bacopa monnieri*, a native wetland plant
ʻākulikuli – *Sesuvium portulacastrum*
ʻākulikuli kai – *Batis maritima* or pickleweed, a non-native wetland plant
ʻEwa - Place name on Oʻahu west of Pearl Harbor, but frequently used to indicate direction on leeward Oʻahu; i.e., to the west (towards *ʻEwa*)
kalo - Taro (*Colocasia esculenta*)
kaluhā - *Bolboschoenus maritimus*, a native bulrush.
kiawe - *Prosopis pallida*; non-native algaroba tree.
loʻi - A pond field for growing *kalo*.
loko - A (typically) estuarine or freshwater pond.
makahā - The sluice gate of a fishpond
makai - Direction towards the sea, towards the coast.
mauka Direction towards the mountains, inland.
muliwai Broadly: estuarine; but more specifically a natural pond at the mouth of an intermittent stream held behind a beach.

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APPENDIX A. Wetlands and Deepwater Habitats Classification Key to Codes

Chapter 1

Puuloa Rifle Range and Iroquois Point Lagoon to Honouliuli Unit, PHNWR

The lands west of the entrance channel to Pearl Harbor are known as Pu'uloa. Navy property in this area includes the Puuloa Rifle Range (on the south shore of O'ahu in the 'Ewa District, the adjacent Iroquois Point Housing directly west of the entrance channel, and Naval Magazine Pearl Harbor (NAVMAGPH), West Loch Branch, extending along the west side of Pearl Harbor all the way to Hono'uli'uli. The Honouliuli Unit of the Pearl Harbor National Wetland Refuge (PHNWR) is located at the western end of Navy property just inland from the south shore of West Loch. All of this area is geologically part of the 'Ewa Plain, an ancient coral reef formation that developed during the late Pleistocene, with the upper portion probably representing the +7.5 m Waimanalo Stand of the sea. Thus, the shoreline in this area tends to rise abruptly and limestone rock and soils are present from the shore inland. Pearl Harbor locations covered in this chapter correspond to most of ACOE (1999) PH Segments 1 and 2.

Puuloa Rifle Range

No wetlands or inland water bodies are known from the Puuloa Rifle Range parcel. The facility borders a beach along the ocean shore.

Iroquois Point Housing Lagoons

Within the Iroquois Point Housing are two man-made lagoon basins connected by pipe culverts beneath 106th Avenue; the larger eastern or outer lagoon opens onto the entrance channel of Pearl Harbor midway between Iroquois Point and Hammer Point. The outer lagoon is used as a yacht basin; the channel connecting to Pearl Harbor is deep enough to accommodate small boat and sailing yachts (Fig. 1-01). The following description of the lagoons is taken from *AECOS* (2006, p. 2):

> Iroquois Point is owned by the U.S. Navy and has been the site of Naval Housing until recently leased to Hunt Building Company, Ltd. (Hunt). The housing and associated infrastructure at Iroquois Point dates from 1959 and the early 1960s[1]. The housing area was developed in an area of mostly kiawe trees

[1] ACOE (1999) shows two aerial photographs obtained from R.M. Towill Corp: One (dated September 1950) shows what appears to be a large area of cleared land in and around the area later occupied by the lagoons, and the other (dated June 13, 1962) shows the completed Naval housing area and lagoons.

(*Prosopis pallida*) and koa-haole (*Leucaena leucocephala*) scrub. The lagoons were then a large depressed area in the midst of the forest, one that probably held shallow water features part of the year, and was a salt flat the remainder of the time. Presumably, this environment was something like that of the Nu'upia Ponds on Marine Corps Base Hawaii at Kane`ohe Bay (see AECOS, 1983, 1985; Wilcox et al., 1998).

Figure 1-01. The outer lagoon at Iroquois Point Housing is a yacht basin. The shoreline is a man-made revetment of boulders.

In Hawaiian times, this place was part of the 'ili (land division) of Pu'uloa and was known for an offshore fish trap called Pakuli built on the reef off Hammer Point at the mouth of Pearl Harbor (Bryan, 1935; Sterling and Summers, 1978). A commercial salt works was established inland after the 'ili of Pu'uloa was purchased by Isaac Montgomery in 1849, producing salt into the early 1900's (Clark, 2002). During and after the Second World War, development of various facilities along the shore of Pearl Harbor was encroaching southward into this area as Pearl Harbor Navy Base expanded. By the 1950s, it appears that the interior depression (location of the former salt works) was no longer connected to the Pearl Harbor entrance channel (interpretations from aerial photo in LSB, 1963). The present-day lagoon was dredged from the depression area, and the steepness of the banks suggests fill from dredging (and perhaps other sources)

These photos do not conflict with the LSB (1963) source, as the aerial photographs in that document are from the mid-1950s.

was used to raise the level of the ground on which the housing project was then built around the lagoon. At this time, two "separate" ponds were formed with a narrow connection between them. A road was placed across the connection, and water exchange maintained through large culverts beneath the road.

The previous (ACOE, 1999) description of this "wetland" (ID ..2231, ..2232. 2333 through ..2338) was that of a lagoon with a dense growth of mangrove along the shore, nearly completely surrounding the inner lagoon and the innermost part of the eastern or outer lagoon. Likewise, Guinther & David (2001) noted "[a]round the margin of the lagoon, the vegetation is dominated by kiawe, red mangrove (*Rhizophora mangle*), and low-growing pickleweed (*Batis maritima*)."

Figure 1-02. Removal of mangroves underway along shore of the inner lagoon at Iroquois Point Housing in June 2004. Trees were cut by hand in the water, then lifted out with a crane on the shore. Original shoreline here is placed (mostly limestone) boulders (see Fig. SP1-01).

In 2004, permission was obtained from the ACOE for Hunt Building Company, Ltd. to remove the mangroves from the area (Fig. 1-02). In areas of dense mangrove growth, the trees had essentially isolated the housing units from use of the lagoon (e.g., the inner lagoon was not even visible from adjacent housing

units) and large amounts of flotsam was collecting at the shoreline among the prop roots of the mangrove (also noted by ACOE, 1999). A biological resources assessment document (*AECOS*, 2006b) was prepared to accompany the application by Hunt Building Company, Ltd. to add cabanas on pilings in the lagoon as part of their efforts to enhance amenities at Iroquois Point Housing. The resources assessment document includes a description and photographs of the marine life inhabiting the essentially marine lagoon environment. A very brief description of the biota of the lagoons is found in Guinther & David (2001).

Observations on the aquatic biota of the lagoons were made on September 1, 2006. Observations were limited to several shoreline areas on each lagoon (corresponding to ID ..2232, ..2233, ..2234, and ..2235; results are given in Table 1-01). The lagoons were visited again on September 15 (3 PM) and salinity measurements taken, yielding 33 ppt for the inner lagoon and 34 ppt for the outer lagoon (close to seawater salinity). The predicted high tide on that date (at Bishop Point, Pearl Harbor) was 2.1 ft at about noon.

Establishing the "wetland" status of the lagoons at Iroquois Point Housing is difficult. Clearly most of the area is not wetland as defined by the ACOE (ACOE, 1987). This aquatic feature is a man-made basin, the substratum at the shore is mostly boulder revetment, and the vegetation is not hydric (although modified from a narrow margin of mangrove growth in many areas). However, in some shoreline sections, the land does slope gradually into the subtidal, and wetland indicator plants (e.g., pickleweed) are or could become established (see Fig. 1-03). The lagoons have an open connection to the ocean (via the Pearl Harbor entrance channel), are tidal, and therefore are—down from the high tide line—jurisdictional waters.

The NWI designation (USFWS, 2007) for this area is E1UBL (the lagoon) and E2FO3N: estuarine, intertidal, broad-leaved evergreen forested, regularly flooded wetland, for the no longer existing mangrove at the shore. A better coding would be E1UBHx, reflecting the estuarine subtidal nature (coded E1), the sedimentary bottom (UB), and the fact that the lagoons are permanently flooded and excavated or man-made (Hx). The shoreline areas of rock revetment become E2RSNx.

Naval Magazine Pearl Harbor, West Loch Branch

Directly north of Iroquois Point Housing is Naval Magazine Pearl Harbor, West Loch Branch (NAVMAGPH). Nearly all of the shoreline north from the mouth of the Iroquois Point Lagoons, along the west side of the Pearl Harbor entrance channel and the long southwest shore leading to West Loch, is a sea cliff of variable height (between 3 and 18 ft or 1 and 5 m; see SP1-02) eroded into the ancient coral reef formation of the 'Ewa Plain. In many places, docks (many now

abandoned) line the shore. Gently sloping shoreline and or shallow mud flat areas are rare, in part because no streams enter Pearl Harbor in this area: the nature of the coastline is erosional rather than depositional, in contrast to the northern parts of Pearl Harbor where many streams draining central O'ahu contribute sediment loads to deltas building out from the shore.

Figure 1-03. The shore of the inner lagoon near the community center. In some areas the shore is not armored and the fill is eroding. The resulting broad intertidal and subtidal shallows encourages aquatic plants such as pickleweed and mangrove seedlings as seen here.

Interior areas of NAVMAGPH are thought not to have any wetlands (ACOE, 1999) and we would concur that inland wetlands would be very unlikely given the nature (geology and land use) of the area. At the shoreline, mangrove growth is scattered, mostly concentrated in small inlets or coves or similar protected situations. On NAVMAGPH, there are five areas of well established mangal (described below), where the trees have reached good size, and formed a stand more than one tree deep. These stands are all subject to tidal rise and fall and therefore constitute jurisdictional waters, although the outer edges may lack hydric soil or even sediment development. In nearly all places visited, the land side, or transition to upland boundary, is evident by a break in the slope (in some cases a cliff; see Fig. 1-04) and/or a deposit of flotsam, although the mangrove canopy may hang out over the upland by several meters.

At NAVMAGPH, the wetlands are typically surrounded by a *kiawe* forest or savannah of variable tree density (although in undisturbed or undeveloped locations, typically of closed canopy), with an undergrowth of buffel grass or Guinea grass. *Milo* trees are common near some wetland boundaries and *koa haole* scrub occurs typically further back from the wetlands or mixed with *kiawe*. The diversity of plants growing close to or at the wetland margin (see Table 1-02) is generally low because these areas have not been disturbed for a long time, and the vegetation has come to be dominated by just a few species.

Figure 1-04. Cliff shoreline section (here only 2-3 m high) near Nichols Point, NAVMAGPH. Pickleweed on right covers a cliff face, while young mangroves cling to rocks at base of cliff and *kiawe* trees overhang this non-wetland shore (see also photo SP1-06).

Loko ʻOkiʻokiolepe ~ Loko ʻOkiʻokiolepe (ID ..2206) is an ancient Hawaiian fish pond located at the shore near the NAVMAGPH road intersection of G Avenue and 15th Street. The margins of the pond are so completely overgrown with mangrove, that evidence of a pond wall is nearly completely obscured and the open, middle of the pond glimpsed only through dense tree growth. Evidence can be seen in aerial photographs of openings at either end of the outer wall, but these are becoming obscured by mangrove growth. The growth

of *Rhizophora* is so dense that, with only minor exceptions of some *Batis*, no other plants are present within the wetland. Most of the interior edge of the pond is marked by a low escarpment, generally less than 1 m (2+ ft) high of limestone outcrops, or a clear transition from a sloping shore dominated by buffelgrass (in areas where the canopy is open), *kiawe,* and *milo* into the arching mangrove prop roots. *Batis* occurs in scattered open areas on the north side among the *kiawe* where it is growing well above the wetland boundary.

This pond was one of the study sites visited by Char (2000), although no site specific information is provided in her report. Dollar & Brock (undated) include a brief description (presumably from the same time period) which found the outer wall intact although partially collapsed, and, like nearly the entire enclosed pond, covered by mangrove. The INRMP for NAVMAG Pearl Harbor (NAVFACENGCOM, 2001, p. 3-18) describes the pond thusly:

> The pond has been identified as being of historic importance because it is one of a few fishponds left in Pearl Harbor where many had existed in the past. It is also considered significant in that it [the wall] was constructed of stacked coral blocks rather than of basaltic stone, the latter being the more common method of constructing fishponds in the Hawaiian Islands. The pond wall is 656 feet (200 meters) long and encloses an area of approximately 4.5 acres (1.8 hectares).

Beyond the north end of the pond is a low cliff around 2 m (or 5-6 ft) high and an inlet, with mangroves clinging to the rocky shore below the cliff. The shoreline north (to Loko Pamoku) and south (to the entrance of Iroquois Point lagoons) of Loko ʻOkiʻokiolepe is a low cliff supporting mostly kiawe above the shore, with only scattered, small mangrove trees established at the water's edge.

The NWI (USFWS, 2007) designation of Loko ʻOkiʻokiolepe is E2SS3N (estuarine, intertidal, broad-leaved evergreen scrub-shrub, regularly flooded) wetland, which is inaccurate and the E2FO3P (estuarine, intertidal, broad-leaved evergreen forested, irregularly flooded) applied to an adjacent mangal is better with the exception that "regularly flooded" would be more correct (i.e., E2FO3N) for tidal mangal. The central open pond is coded E2ABM (estuarine, intertidal, aquatic bed, irregularly exposed), aligning it ecologically with the shallows in front of the pond, which may or may not be precisely correct.

Loko Pamoku ~ The Army Corps report (ACOE, 1999, p. 17-18) provides this description of Loko Pamoku (ID ..2207):

This is a smaller pond than Loko Okiokiolepe. It is accessed by going down G Avenue headed towards Waipahu and taking a right turn onto a dirt road just past the secured bunkers. This fishpond is also colonized by mangroves with patches of pickleweed behind it.

Figure 1-05. Boundary between wetland and upland (north edge of Loko Pamoku on old fill) with mangrove trunks on left and in background and kiawe trees growing on upland. Note intermixing of canopy.

We surveyed a feature fitting the description along the shore northwest of ʻOkiʻokiolepe and north of a very imposing area of secured bunkers along G Avenue just south of the NAVMAGPH Restricted Area. Physical evidence relating to whether or not this feature is an ancient fishpond is gone. The feature consists of two mangrove choked inlets separated by a narrow shoreline belt of mangrove below a low cliff. No outer pond wall is evident. On the north side, it appears fill was deposited in the pond or up to the pond edge (Fig. 1-05).

Within each cove or inlet, wetlands are entirely covered by red mangrove, and the margins are much as described above for Loko ʻOkiʻokiolepe. Several patches of pickleweed occur inland of the mangrove surrounded by the *kiawe* forest, but these seem to be clearly upland sites. The NWI designation (USFWS,

2007) for this area of the shore is E2FO3N: estuarine, intertidal, broad-leaved evergreen forest, regularly flooded wetland, which is correct. The open "pond" at the front is E2ABN (estuarine, intertidal, regularly flooded aquatic bed; see Loko ʻOkiʻokiolepe discussion, above). A large area along this coast (redrawn since USFWS, 1999) is coded E2FO3P (implying an irregularly flooded mangal), which is in fact mostly a *kiawe* forest above a cliff at the shoreline and not an environment that floods.

Shoreline Mangrove and Mangal Wetlands ~ In addition to the two named fishponds, at least three clusters of mangroves represent wetlands along the shore in the northern part of NAVMAGPH (accessed through the northern gate at the end of Iroquois Pt. Road). Several, presently distinct clusters of mangrove growth at the shore and two mangrove islets form a mangal off the former officers club on Arizona Loop. These mangal features (IDs ..2208 through ..2211) lie at the base of a high (5-6 m or 15-18 ft) cliff (and the islets lie just off the shoreline mangal). As with the fishponds, these wetland features are entirely dominated (essentially, defined) by red mangrove, and the landward boundary between the mangrove and uplands is sharp.

The outer wall of an enclosed cove or fishpond (ID ..2213) was constructed of large concrete pieces (old concrete pilings) laid end to end to form a wall roughly 1 meter (3 ft) above the high tide level and roughly 1.7 m (5 ft across), with at least one control-type opening or *makahā*. Nearly the entire pond is covered by a growth of red mangrove, although aerial photographs and ACOE (1999, Fig. 10) show an interior open pond. Because of the mangrove growth, the concrete wall could not be accessed all the way across to the carefully engineered concrete walkway (Fig. 1-06) that surrounds the east and south sides of an open water area at the north end of this same cove. But the entire area was clearly modified to create what seems to be a recreational swimming area: the concrete walkway wall is reached by a well-constructed and rather formal looking stairway that leads down from the former Nichols Point officers housing area at the end of B Avenue. The wall extending northwest from the south end of the cove is less exacting in its construction (see photo SP1-03), yet still appears to have been used as a walkway as well as a barrier enclosing a portion of the cove. A shelf (former road or graded shore) lies along the inland margin, where the land rises abruptly, but not as a cliff, lending credence to the idea that this feature was a cove modified for recreational use. ACOE (1999) regarded the shoreline modifications as undocumented with respect to their files.

An expanded shoreline mangal (ID ..2214; with one small mangrove islet) lies off the north side of Nichols Point. The wetland begins at the base of a moderately high cliff and extends, with only red mangrove, a variable distance out from the

shore. Scattered occurrences of mangrove occur along the shore to the west of Nichols Point. Behind the shore is Navy land leased to others for farming and located outside the NAVMAGPH fence. This area was not accessed for the present survey.

Figure 1-06. Portion of the south wall of an enclosed swimming area at Nichols Point. Mangroves are destroying this potentially significant historical feature.

All of the shoreline mangrove wetlands described above are now indicated on NWI maps (USFWS, 2007). These mangals are all coded E2SS3N (estuarine intertidal broad-leaved evergreen scrub-shrub, regularly flooded) in the northwest part of NAVMAGPH. In our interpretation, only E2FO3N could be applied to such mature mangrove areas. Further, open areas in the so-called "swimming pool" area are not coded at all as were similar habitats at Loko ʻOkiʻokiolepe and Loko Pamoko. One area mapped as E2FO3N is upland covered by *kiawe* forest with a cliff at the shore.

Honouliuli Unit, Pearl Harbor National Wildlife Refuge

The Honouliuli Unit of the Pearl Harbor National Wildlife Refuge (PHNWR) is located behind the southwestern shore of West Loch, Pearl Harbor. The refuge encompasses an area of 37 acres (15 ha) divided into two shallow ponds (ID ..3164 and ..3165), with a drainage ditch (ID ...3158) between them (see photo SP1-04 and SP1-05). The refuge is managed by the U.S. Fish & Wildlife Service under a cooperative agreement with the U.S. Navy, which owns the land.

The two ponds are managed as fresh water wetlands (USFWS at URL: http://www.fws.gov/pacificislands/wnwr/opearlnwr.html). Much of the vegetation in the NWR is actively managed, as are water levels in the ponds; therefore the diversity of wetland plants is far greater than observed in wetlands elsewhere around Pearl Harbor (see Table 1-02). Native plants are planted or encouraged and no one species is allowed to become dominant across the wetland.

As a managed wildlife refuge, wetland conditions are maintained to particularly encourage listed (endangered or threatened) waterfowl. Large numbers of Hawaiian stilt and Hawaiian coot were observed, along with other birds (Table 1-01). The NAVMAG Pearl Harbor INRMP (NAVFACENGCOM, 2001) contains additional information on this wildlife refuge.

National Wetland Inventory maps for the PHNWR, Honouliuli Unit are provided at the NWI website (USFWS, 2007). The refuge ponds are classified differently: PABHx: palustrine, aquatic bed, permanently flooded, excavated for the western pond and PEM1/USCx: palustrine persistent emergent vegetation seasonally flooded/unconsolidated shore, excavated for the eastern pond. Offshore areas are correctly identified as E1UBL: Estuarine subtidal unconsolidated bottom (i.e., a mud or sand-bottomed estuary). The central drainage ditch between the ponds is coded E1UBLx, essentially an excavated subtidal feature. Curiously, a moderately large area immediately to the east of PHNWR is classified PSS3C: palustrine, broad-leaved evergreen scrub-shrub, seasonally flooded. We believe this corresponds to a small hill within the refuge fenceline.

Beyond the wildlife refuge, the shoreline turns northward across the mouth of Hono'uli'uli Valley, where the coast becomes mixed erosional/depositional in nature, with a consequent increase in aerial extent of conditions favoring mangal formation. This part of Pearl Harbor (upper West Loch) is discussed in Chapter 2.

Tables 1-01 and 1-02 summarize biological observations (fauna and flora, respectively) made in 2006 at various wetlands located in the upper East Loch

area. Table 1-03 summarizes differences between what was reported for this area as present and surveyed in 1999 (ACOE, 1999) and our 2006-7 observations.

Table 1-01. Aquatic biota listing for Iroquois Point to PHNWR (Honouliuli Unit).

Species listed by family	Common name	Notes	Wetland ID No. 23304 (a)	22061 (b)	23164	23165
	INVERTEBRATES					
MOLLUSCA, BIVALVIA						
OSTREIDAE						
Crassostrea virginica	Amer. oyster		A			
MOLLUSCA, GASTROPODA						
THIARIDAE						
Melanoides tuberculata	Red-rimmed Melania					A
ARTHROPODA, CRUSTACEA						
CHTHAMALIDAE						
Chthamalus proteus	Caribbean barnacle		C			
GRAPSIDAE						
Metopograpsus thukuhar	*'alamihi*		O			
ARTHROPODA, INSECTA						
DIPTERA						
CULICIDAE						
Indet.	(mosquito larvae)					
ODONATA						
AESHNIDAE						
Anax junius	Green darner					U
LIBELLULIDAE						
Crocothemis servillia	Scarlet skimmer					C
Orthemus ferruginea	Roseate skimmer					O
Pantala flavescens	Globe skimmer					R
Tramea lacerata	Black saddlebags					C
COENAGRIONIDAE						
Ischnura ramburii	Rambur's damselfly					O
	VERTEBRATES					
PISCES (fishes)						
CICHLIDAE						
Sarotherodon melanotheron	black-chin tilapia					A

Table 1-01 (continued).

Species listed by family	Common name	Notes	Wetland ID No. .2334 (a)	.2206 (b)	.3164	.3165
KUHLIIDAE						
Kuhlia xenura	*aholehole*		C			C
MUGILIDAE						
Mugil cephalis	*ʻamaʻama*		C			
POECILIIDAE						
Gambusia affinis	mosquitofish		O			C
SPHYRAENIDAE						
Sphyraena helleri	barracuda		R			
AMPHIBIA						
RANIDAE						
Rana catesbeiana	American bullfrog					R
AVES (birds)						
ANATIDAE						
Anas platyrhynchos	mallard					C
ARDEIDAE						
Bulbucus ibis	cattle egret		U			O
Nycticorax nycticorax hoactili	black-crowned night heron, *auku'u*					U
CHARADRIIDAE						
Pluvialis fulva	*kolea*		R			A
RALLIDAE						
Fulica alai	*ʻalae keokeo*					A
RECURVIROSTRIDAE						
Himantopus mexicanus knudseni	*aeʻo*					A
SCOLOPACIDAE						
Arenaria interpres	*ʻakekeke*					C
Calidris alba	*hunakai*					O

KEY TO SYMBOLS USED IN TABLE: 1-01

Abundance categories:

R – Rare – only one or two individuals seen.
U – Uncommon – several to a dozen individuals observed.
O – Occasional – regularly encountered, but in small numbers.
C – Common - Seen everywhere, although generally not in large numbers.
A – Abundant – found in large numbers and widely distributed.
P – Present – noted as occurring, but quantitative information lacking.

Table 1-02. Flora listing for Iroquois Point to PHNWR (Honouliuli Unit) wetlands.

Species listed by family	Common name	Notes	Wetland ID No. .2334 (a)	.2206	.2207	.2208	.3164 (b)
AIZOACEAE							
Sesuvium portulacastrum	*ʻākulikuli*	(2)					R
Trianthema portulacastrum	---	(1)					U
AMARANTHACEAE							
Achyranthes aspera	---	(1)					R
Alternanthera pungens	khaki weed	(1)	R				
Amaranthus spinosus	spiny amaranth	(1)					R
Amaranthus viridis	slender amaranth	(1)	R				
ASTERACEAE							
Calyptocarpus vialis	---	(1)	U				
Pluchea carolinensis	sourbush	(1)			U	U	
Pluchea indica	Indian fleabane	(2)	U				A
Pluchea X *fosbergii*	fleabane hybrid	(1)			U		R
Verbesina enceliodes						U	
BATACEAE							
Batis maritima	*ʻākulikuli kai*		O	O	O	U	C
BORAGINACEAE							
Heliotropum curassavicum	seaside heliotrope	(1)	U				C
CHENOPODIACEAE							
Atriplex semibaccata	Aust. saltbush	(1)				U	C
CONVOLVULACEAE							
Jacquemontia ovalifolia	*paʻu-o-hiʻiaka*	(1)					O
Ipomoea cairica	*koaliʻai*	(1)					U
CUCURBITACEAE							
Coccinia grandis	*ivy gourd*	(1)			U		
CYPERACEAE							
Bolboschoenus maritimus	*kaluhā*						A
Cyperus rotundus	nut sedge	(1)					O
Mariscus javanicus	*ʻahuʻawa*						O
EUPHORBIACEAE							
Chamaesyce hirta	garden spurge	(1)	U				U
Chamaesyce hypericifolia	graceful spurge	(1)	U				U
Chamaesyce prostrata	prostrate spurge	(1)	U				
Phyllanthus debilis	---	(1)	U				

Table 1-02 (continued).

Species listed by family	Common name	Notes	Wetland ID No. .23344 (a)	.22066	.22207	.22208	.31644 (b)
FABACEAE							
Desmanthus virgatus	virgate mimosa	(1)		U			O
Indigofera spicata	*creeping indigo*	(1)					U
Leucaena leucocephala	*koa haole*	(1)		U			O
Pithecellobium dulce	*ʻopiuma*	(1)					R
Prosopis pallida	*kiawe*	(1)	O	A	A	C	U
Samanea saman	monkeypod	(1)	R				
MALVACEAE							
Sida ciliaris	---	(1)					U
Sida fallax	*ʻilima*	(1)			O		
Sida spinosa	prickly sida	(1)					U
Thespesia populnea	*milo*	(1)	O	C	C		
NYCTAGINACEAE							
Boerhavia coccinea	false *alena*	(1)	R				U
PASSIFLORACEAE							
Passiflora foetida	love-in-the-mist	(1)		O			O
POACEAE							
Cenchrus ciliaris	buffel grass	(1)		A		A	U
Chloris radiata	plushgrass	(1)					C
Cynodon dactylon	Bermuda grass	(1)	C				A
Eleusine indica	wiregrass	(1)					U
Leptochloa uninervia	sprangletop						C
Paspalum vaginatum	seashore paspalum						C
Sporobolis virginicus	seashore rushgrass	(1)					U
Sporobolis diander	---	(1)					U
Urochloa maxima	Guinea grass	(1)			A		O
PORTULACACEAE							
Portulaca oleracea	pigweed	(1)					
RHIZOPHORACEAE							
Rhizophora mangle	red mangrove		O	A	A	A	U
SCROPHULARIACEAE							
Bacopa monnieri	*ʻaeʻae*						A
SOLANACEAE							
Solanum americanum	*popolo*		R				

Table 1-02 (continued).

			Wetland ID No.				
			..2334	..2322	..2206	..2208	..3164
Species listed by family	Common name	Notes	(a)				(b)
TYPHACEAE							
Typha latifolia	cattail						C

Notes:

(a) The listing for ..2334 includes ..2332, ..2333 and ..2335.
(b) The listing for ..3164 includes ..3165 and ..3158.
(1) Typically not a vegetation of wetlands, but growing around margin.
(2) Marginal wetland vegetation member; more typically growing at edge of wetland, but sometimes in wetland.

Table 1-03. Summary of Changes since 1999

Site	Description	Change since 1999	Wetland ID
Golf course ponds	Eight ponds surveyed, none discussed*	More ponds exist; no ponds surveyed in 2006.	..1197 - ..1204
Puuloa Rifle Range	no wetlands	no change.	n/a
Iroquois Point Lagoons	Man-made marine ponds with fill (rock or eroding) shore	Mangroves removed; minimal or no wetlands present.	..2231- ..2338
Loko ʻOkiʻokiolepe	Mangal within pond	Mangrove expanding.	**..2206**
Loko Pamoku	Mangal within pond	Mangrove expanding.	**..2207**
Unnamed mangal	Shoreline mangal	Mangrove expanding.	**..2208 - ..2212**
Unnamed pond	Mangal within pond	Mangrove expanding.	**..2213**
Unnamed mangal	Shoreline mangal	Not seen in 1999.	**..2214**
PHNWR, Honouliuli	Refuge wetlands	No change in size or status.	**..3158. ..3164, ..3165**

Following are supplemental photographs (SP) for Chapter 1.

SP1-01 (right): area of removed mangrove trees at Iroquois Point Housing (same location as shown in Fig. 1-02), with community improvements underway in September 2006).

SP1-02 (left): typical NAVMAGPH cliffed shoreline with a forest of *kiawe* (*Prosopis pallida*) growing above the cliff line.

SP1-03 (left): wall structure across front of southern end of a pond at Nichols Point. Feature is deep inside a mangrove forest.

SP1-04 (right): The central drainage ditch at Hono'uli'uli Unit of the Pearl Harbor NWR. The shoreline mangal on West Loch is seen across the back.

SP1-05 (left): Larger of the two ponds at Hono'uli'uli Unit of the Pearl Harbor NWR. The open nature and diversity of wetland plants in a managed system such as this, is in sharp contrast with the low diversity and excessive alien plant growth of most unmanaged wetlands around Pearl Harbor.

SP1-06 (above): Nichols Point. Composite photograph showing mangrove growing at base of cliff shore (left) with *kiawe* immediately above. Islet of limestone rock offshore on right is oddly not colonized by mangrove, perhaps lacking any surrounding shallows for propagules to gain purchase.

Chapter 2

West Loch Shoreline

West Loch is the westernmost of the three major divisions of Pearl Harbor. The western shore borders an area of extensive recent housing developments in what used to be agricultural lands surrounding Hono'uli'uli. Navy property in the upper Loch is limited to an offshore islet and a former fishpond known as Laulaunui and the east side of the Loch (Waipi'o Peninsula; covered in Chap. 3). Inland of the lower west shore is a shallow valley or coastal lowland around Hono'uli'uli Stream. Much of this low ground is occupied by a City and County of Honolulu municipal golf course, where remnant water bodies and wetlands are present between areas of fill. This area also includes the West Loch Shoreline Park (accessed off Laulaunui Street) which incorporates all of the coastal wetlands still extant in the area. The Honouliuli Unit of the Pearl Harbor National Wetland Refuge (PHNWR; discussed in Chap. 1) is located at the southern end of this western shore. The areas encompassed in Chapter 2 correspond to most of ACOE (1999), Segment 3.

Geologically, much of this coastal segment is alluvial material eroded onto the limestone 'Ewa Plain, an ancient coral reef formation formed during a Pleistocene high stand of the sea. Thus, the shoreline in this area tends to rise abruptly and limestone materials are present behind the shore beneath a mantle of lateritic alluvium.

West Loch Shoreline Park

The low area around the mouth of Hono'uli'uli Stream was at one time a shallow inlet or perhaps a broad tidal flat that extended inland up the stream as an extensive wetland feature fed by numerous springs that issued from the edge of the low escarpment at the edge of the 'Ewa Plain. The once extensive coastal wetland was partially cut off from West Loch by the Oahu Railroad & Land Company (OR&L) right-of-way (r-o-w) running between the 'Ewa Plantation at 'Ewa, passing around Pearl Harbor, and then on to Honolulu Harbor. Although the stream itself was bridged, the berm supporting the railway physically divided the wetland, partially isolating ponds and lowlands on the west from the Pearl Harbor shore on the east. The OR&L berm (TMK: 9-10-17:044; owned by the State of Hawai'i and now an energy corridor) supports a bikeway/jogging path in the park (although the paved bikeway goes inland around Ka'auku'u Fishpond).

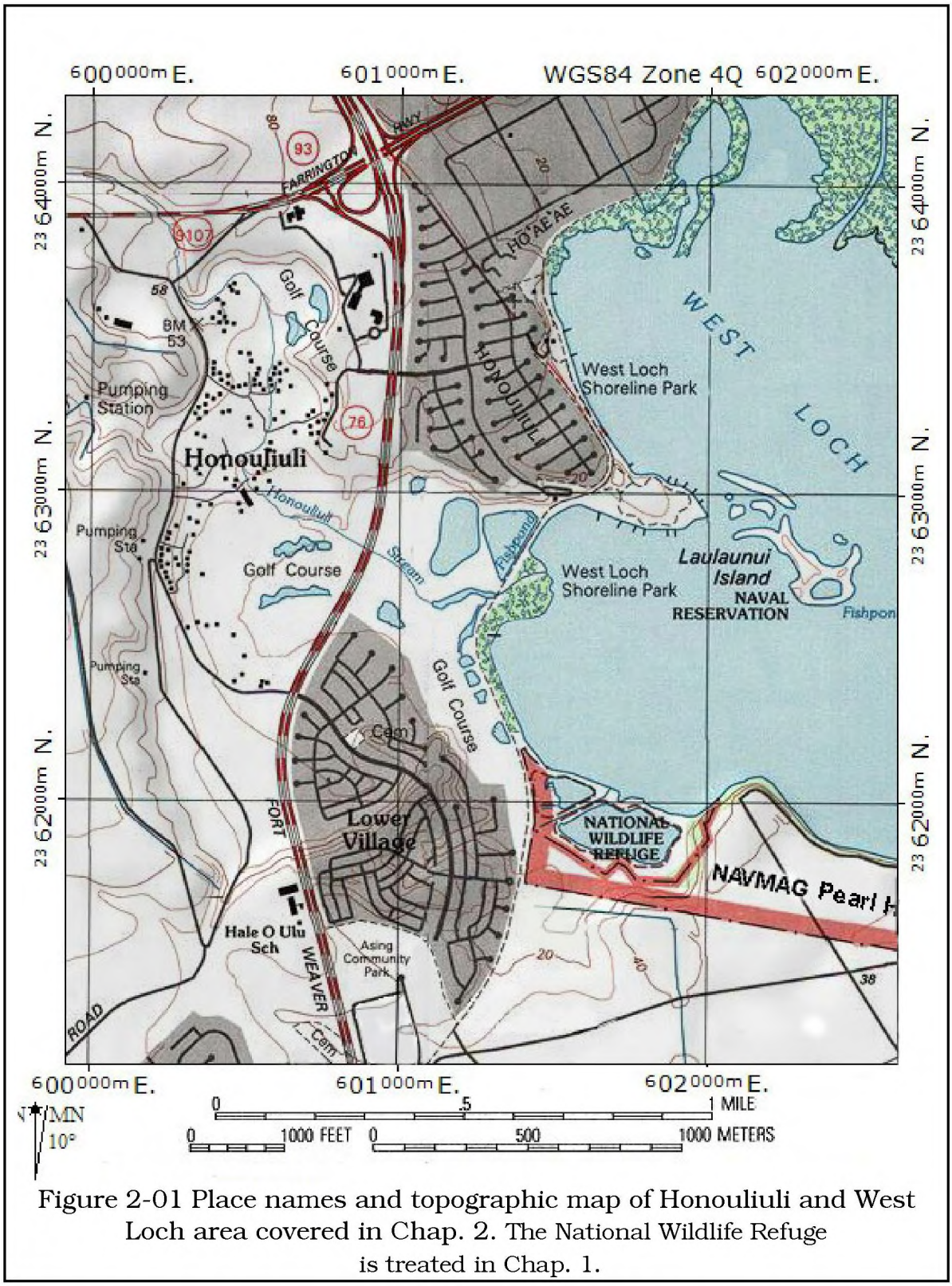


Figure 2-01 Place names and topographic map of Honouliuli and West Loch area covered in Chap. 2. The National Wildlife Refuge is treated in Chap. 1.

'Ewa Plantation was started in 1890 after the railway was built, and springs around Hono'uli'uli were tapped to support sugar cane production on the 'Ewa

Plain. Over time, the wetlands and likely extensive *kalo lo'i* existing in the valley of Hono'uli'uli Stream were filled and the land developed (the West Loch Golf Course now occupies much of this area).

The fishpond on the north side of Hono'uli'uli Stream (Ka'auku'u; ID ..3181; see photo SP2-01) and the depressions that lie between the railroad berm and the golf course that were once used to harvest salt and more recently for aquaculture (ACOE, 1999), are now heavily overgrown with mangrove, although open water remains in about the western 60% and northern 5% of the fishpond, and in the hidden interior of the southernmost salt pond (ID ..3162). Salinity in Ka'aku'u Fishpond was 16 to 24 ppt (brackish) in different places, measured on 09/15/06. Salinity along the mangrove shore (ID ..3166) east of the old OR&L r-o-w was 32 ppt (marine) at this time.

All of the once open bodies of water west of the OR&L r-o-w were fed by either tidal flux via Hono'uli'uli Stream or culverts or bridged openings in the old railway berm. A separate opening with weir boards (see photo SP2-02) that once fed the three ponds used for salt production (IDs ..3160, ..3161, & ..3162) is no longer functional and water now enters on high tide from Hono'uli'uli Stream (ID ..3171) through a narrow, mangrove clogged channel. The flow finds its way south through a mangrove forest (ID ..3178) and eventually across an extensive *Batis* flat (ID ..3163; see photo SP2-04) to an open pond. Salinity in the mangrove at ..3178 was 18 ppt, and in the pond at ..3163 was 15 ppt on 09/15/06. Because this tidally influenced pond lacks emergent vegetation, it is not a wetland, although it would be jurisdictional "waters of the U.S."

The depression continues south beyond the brackish water pond where the wetland is apparently influenced only by freshwater, and therefore separately identified herein as ID ..3159. This wetland is distinct from wetland ID ..3163 (with which it was mapped in 1999), a distinction that is physical as well as evident from the nature of the vegetation. Wetland ID ..3159 is densely covered by dayflower (*Commelina diffusa*) suggesting a fresh water regime, whereas wetland ..3163 is more typical for this area: a pickleweed flat behind mangrove. Thus, there is likely no tidal connection between the *Commelina* marsh and the open pond to the north. The salinity in ..3159 on 09/15/06 was only 1 ppt (nearly fresh water).

West Loch Shoreline Park extends northward along the West Loch shore to the point where the shore begins to curve eastward. In this area, there is evidence of ongoing removal of mangroves within the park right up to the northern park boundary. In the north part of the park is a small pond (ID ..3185) associated with a residence. The pond appears fed by a spring as there is a small outlet ditch that flows towards the West Loch shore. In 1999, this pond was

described as a "taro lo'i" (*kalo lo'i*), but in 2006 it contained only one taro plant and was stocked with water lilies.

Figure 2-02. West side of West Loch at the mouth of Hono'uli'uli Stream, an area of once extensive wetlands showing locations discussed in text. GCP = golf course pond.

Features in this area are now easily matched with the NWI maps at USFWS (2007). The shoreline mangal (ID ..3166, ..3179, ..3180), as well as the fishpond (ID ..3181), are classified E2SS3N: estuarine, intertidal, regularly flooded broad-leaved scrub-shrub. This description might better fit shoreline areas newly invaded by mangrove or where mangrove is poorly established (*Rhizophora* exists as a shrub) or pickleweed flats; in our opinion, the more appropriate classification for mangal would be E2FO3N: estuarine, intertidal, regularly

flooded broad-leaved forest. The pickleweed flat towards the south (excluding the pond) is coded E2EM1N: estuarine, intertidal, emergent persistent vegetation, regularly flooded. We would code this area E2SS3N to reflect the fact that *Batis* is an evergreen shrub. The most recent version of the NWI (USFWS, 2007) does not differentiate our palustrine wetland (ID ..3159) from the pickleweed area.

The latest version of the NWI (USFWS, 2007) indicates no wetlands along the estuarine reach of Hono'uli'uli Stream (the channel is E1UBL), but codes the mangrove areas at the stream mouth and in West Loch south of the stream as E2FO3N (= mangal; ID ..3179 in part), but inconsistently also E2SS3N (IDs ..3160, ..3161, ..3162, ..3166, ..3178, ..3179 in part, and ..3180). An area of pickleweed behind the shoreline mangal is coded E2EM1N: estuarine, persistent emergent vegetation, regularly flooded. We would suggest E2SS1N since *Batis* is a shrub.

West Loch Golf Course

The West Loch Golf Course (a City & County of Honolulu municipal course) is located inland from the City & County West Loch Shoreline Park and includes a number of water features (water hazards), some of which can be regarded as wetlands in character, although exempted from consideration as waters of the United States (that is, are not jurisdictional) for the reason that they are isolated and non-naturally occurring ponds (see 33 CFR § 328.34[a]). Presumably, jurisdiction would be decided only after a significant nexus analysis (see pp. 15-16). The golf course has seven water features large enough to appear on the topographic map (Fig. 2-01) that also appear on recent satellite images (Microsoft Corp., 2006). The ACOE (1999) shows a total of six wetlands, one (ID ..3171) being a small area below St. Francis Medical Center where there are today two golf course ponds. Both of these ponds are man-made water traps with the shoreline constructed of concrete and rock (crm). ID ..3171 may have had some established emergent plants when viewed in 1999. The second largest pond (ID ..3168) is located along the south boundary of the course on the west side of Fort Weaver Road. This pond (Fig. 2-03) had no open water at the time of our visits (August and January, 2006-07): the surface being completely overgrown with water hyacinth (*Eichhornia crassipes*; see photo SP2-05) and the margins covered with California grass (*Urochloa mutica*). Pond ID ..3169 is also completely covered by water hyacinth. Because these are ponds with the majority of the vegetation floating and not rooted emergent plants, only the shallow margins can be classified as wetlands by ACOE definition (ACOE, 1987) but are not waters of the U.S. as defined by ACOE or EPA (40 CFR § 122.2).

Other golf course water features east of Fort Weaver Road were assigned IDs ..3173, ..3182, and ..3183 in ACOE (1999). Feature ID ..3182 is not a wetland at all, but a large reservoir with masonry (crm) banks and is used as a driving range and water storage for the golf course. The other two ponds (..3173 and ..3183) have margins that are wetlands, but probably not jurisdictional waters. Honouliuli Stream (see below) passes through the middle of the golf course in a vegetated swale that includes a wetland.

The NWI (USFWS, 2007) codes the golf course ponds as PEM1Cx: palustrine, emergent vegetation, seasonally flooded, excavated; the open waters are PUBHx: palustrine, unconsolidated bottom, permanently flooded, excavated. In one pond the marginal vegetation is coded as a shrub-scrub (PSS1Cx) and in another as a forest (PFO1Cx).

Figure 2-03. The West Loch Golf Course pond (ID ..3168) along the southern edge of the golf course just west of Fort Weaver Road. Water hyacinth dominates the center of this pond feature.

Hono'uli'uli Stream

Hono'uli'uli Stream arises in several gulches draining the southeast corner of the Wai'anae Mountain and these converge above H-1 freeway to form

Hono'uli'uli Gulch. This area is seasonally very dry and the stream is intermittent. However, perennial flow, perhaps much reduced by pumping from the aquifer, results from springs all along the lower reach of the stream within the broad swale today mostly occupied by the C&C West Loch Golf Course (see above; Nance, 1998).

The ACOE (1999) mapped six different wetlands along the lower stream course (IDs ..3170, ..3172, and ..3174 through ..3177). These wetlands are separated by cart path crossings penetrated by culverts and the Fort Weaver Road highway viaducts. It is clear that at least ID ..3172 (west side of Fort Weaver Road) and ID ..3174 (east side of Fort Weaver Road) constitute a single marsh dominated by California grass over which Fort Weaver Road crosses on concrete pilings. The west side of this marsh extends south, parallel to the roadway, ending at pipe culverts (2 X 36") that provide an outlet for pond ID ..3168. In January 2007 we observed a spring flowing into this pond near the pond outlet[1].

Upstream of the Fort Weaver Road viaduct, Hono'uli'uli Stream occupies a shallow channel (ID ..3170 an ..3172) that was overgrown with vegetation in January 2007. This wetland actually continues beyond the uppermost cart path crossing and into drainage ditches that drain house lots in an area that was perhaps once extensive wetlands along the stream.

Water in lower Hono'uli'uli Stream becomes brackish within wetland ID ..3175. A grove of red mangrove (or mangal) occupies the lower half of this wetland, whereas the upper half and southern margin are overgrown with California grass and presumably freshwater (see Introduction, Fig. 7). Downstream, wetland IDs ..3176 and ..3177 are in reality the tidal channel (estuary) of Hono'uli'uli Stream with narrow mangrove and pickleweed wetlands present along the margins. Englund et al. (2000) reported a salinity of 32 ppt in the mangrove area along the lower stream and 4 ppt in the "upstream reaches of the golf course."

The lower segment of Hono'uli'uli Stream around Fort Weaver road is incorrectly identified in the NWI (USFWS, 2007) as PSS3C: palustrine, evergreen shrub-scrub, seasonally flooded instead of PEM1C: palustrine, persistent emergent vegetation, seasonally flooded. The lowermost palustrine section is correctly coded as PEM1C, but shown as PFO3C further downstream, instead of the correct coding of E2FO3N: estuarine intertidal broad-leaved evergreen forested, regularly flooded wetland.

[1] This fact alone will likely subject golf course pond ..3168 to ACOE jurisdiction.

Former Kahua Meat Co. Pond

The landscape in the area around the former Kahua Meat Co. slaughterhouse at the corner of Fort Weaver Road and Old Fort Weaver Road has changed dramatically in the last decade. The Kahua Meat Co. building no longer exists, and the intersection of the new and old roads has been realigned such that the location of the former facility that utilized a pond to treat slaughterhouse wash-down is difficult to establish. The land that lies south of the West Loch Golf Course between the new and old Fort Weaver roads (TMKs: 9-10-17:010 and 9-10-17:041) appears to be fill and is cut by at least three drainage ditches over 2 m (6 ft) deep and 2-3 m wide; these lead from a low area densely overgrown with California grass (Fig. 2-04).

Figure 2-04. All that appears to remain of the wetland behind the former Kahua Meat Co. is a depression completely overgrown with California grass. However, this is not wetland ID ..3167.

This low area may be the remains of the former pond utilized by the slaughterhouse (located on TMK: 9-10-17:041). The description in ACOE (1999) states "sewage is treated in this pond adjacent to West Loch Golf Course's 10th tee and Kahua Nursery". The ACOE 1999 delineation shows such a pond

feature in an area now occupied by fill with only the drainage ditches described above remaining; these ditches join into a single ditch draining to the golf course pond (..3168) located at the north end of the fill. A spring that might have once fed feature ID ..3167 was observed in January 2007 to now flow over the sloped ground surface at the southeast corner of the golf course pond.

Laulaunui Island

The peninsula on which the City & County Shoreline Park at West Loch lies extends eastward as a submerged feature, rising above the surface as a cluster of islets know as Laulaunui (see Fig. 2-01). Laulaunui refers to one of the offshore islets and a fishpond. The islets are all part of the Naval Reservation and low parts are overgrown with mangrove. The closest mangrove growth is only about 70 m (230 ft) off the tip of the peninsula, while the larger islet is 260 m (850 ft) across shallow water from the park.

ACOE (1999, p. 23) provides the following descriptions:

> ...Laulaunui Island refers to the main island which is the largest and tallest rising 40-50 feet above sea level. To the southeast is a smaller island which appear[s] on aerial photographs to be connected to the main island. However, there is an opening which is covered by American mangrove. A trail has been cut in the coral forming a path between the two islands. The water was 6-12 inches deep between the two islands at high tide. The islands were formed on an old coral reef which contained a lot of old oyster beds at a time when the water level was much higher. *Kiawe* dominates the upland areas with very little grass on the islands. American mangrove covers the shoreline areas and the islets surrounding the main island.
>
> The fishpond is on the seaward [southeast] end of the island. Mangroves obscure the walls and openings, and the interior of the pond is inaccessible by boat. The footprints of several buildings are on this island.

The NWI wetlands of Laulaunui are all classified as E2SS3N by USFWS (2007) and the open water surrounding the mangrove is E1UBL. E2SS3N is an estuarine, intertidal, regularly flooded broad-leaved scrub-shrub wetland. This description might better fit some of the recently invaded areas of mangrove or where mangrove is poorly established (and *Rhizophora* exists as a shrub); the more appropriate classification for mangal would be E2FO3N: estuarine intertidal broad-leaved evergreen forested, regularly flooded wetland.

West Loch, North Shore Wetlands

The bike trail in West Loch Shoreline Park ends at a locked gate, although an unimproved roadway and the energy corridor continue around the north side of West Loch. The corridor tends to lie along the inner edge of the mangrove belt (ID ..3219) which widens substantially into West Loch south of Ho'ae'ae Street in Waipahu. Just west of a bridge over an unnamed drainage, the wetland appears to extend onto the energy corridor (i.e., at high tide water covers part of the road). Free of mangrove, this area supports sedges (*Cyperus difformis* and *Eleocharis* sp.) on salt-encrusted red soil.

The concrete lined Waipahu drainage channel becomes a mangrove-lined channel through the mangal, turning abruptly eastward, parallel with the energy corridor before emptying into a remnant fishpond surrounded and encroached upon by mangrove. The wetland ID ..3219 is shown in ACOE (1999) ending at about the eastern edge of the fishpond wall and becoming wetland ID ..3221 further east, although there appears to be no particular reason for making this division, except the mangrove forest here extends some 1800 ft (600 m) from the energy corridor south into West Loch on the deltaic deposit of Waikele Stream. The stream and former fishponds beside it mark the western edge of the Waipahu Peninsula (covered in Chap. 3).

Waikele Stream drains the second largest watershed on O`ahu (12,540 ha or 30,980 acres) (GDSI, 1994). The floodway incorporates two outlets—the eastern outlet called Kapakahi Stream (see Chap. 3). The latter drains out through a narrow canal on the west side of Waipahu Depot Road. The main channel of Waikele Stream enters West Loch further to the west. Both streams are presently crossed by rusting, iron bridges. Once safe for vehicles, the bridges now support only the petroleum products pipelines of the energy corridor and foot traffic. The channels crossed by these bridges are estuaries of their respective streams.

The mangrove forest off the mouth of Waikele Stream (IDs ..3221, ..4239, ..4240[2]) is the largest area of mangrove in Pearl Harbor, and its origin is widely reported a consequence of the spread of red mangrove across an expanding stream delta from sediment laden run-off eroded from extensive sugar cane lands of central O'ahu, especially in the 1940s and 50s as a result of the introduction of mechanical harvesting methods (Wester, 1981; Char, 2000). Englund et al. (2000) notes this area of West Loch appeared free of mangroves

[2] Plus the isolated single trees or small clusters assigned IDs ..3222 through ..3230 and ..4247 through ,,4250 all located along the advancing seaward edge of the extensive mangal at the mouth of Waikele Stream.

in a 1951 aerial photograph. Subsequent dated photographs (after Wester, 1981) show a steady spread of mangroves across the deltas of Waikele and Kapakahi streams.

Englund et al. (2000, p. 20) describes the mouth of Waikele (that is, the stream mouth out in front of the mangrove belt) thusly:

> At the Waikele Stream mouth, large expanses of tidal mudlflats are exposed at low tide. Tree stumps, shopping carts, tires, abandoned gill-nets, and other urban debris were found strewn throughout this tidal mudflat area. The substrate in the tidal mudflat area consists of thick layers of fine silts, with many areas firm enough to walk on at low tide. However, in some areas it is possible to sink over 1 m (3 ft) deep or more into the fine silt. At low tide, many shallow water pockets are formed in the mudflats near the mangroves, and these extend out several hundred yards into Pearl Harbor.

The NWI maps (USFWS, 2007) classify the extensive mangal in this area as E2FO3N: Estuarine, intertidal, regularly flooded, broad-leaved evergreen (i.e., mangrove) forest. Open waters of West Loch are E1UBL: estuarine subtidal unconsolidated bottom.

Pūpū'olē Wetlands

Two freshwater wetlands (ID No.s ..3217 and ..3218) lie on the *mauka* or north side of the energy corridor road below Waipahu Elementary School and just to the east of a small neighborhood park at the end of Pupuole Street in Waipahu. A description from *AECOS* (2000, p. 26) follows:

> ...the [proposed bikeway] route skirts the extensive mangrove swamp and is bounded on the north (*mauka*) side by a marsh adjacent to Pupuole Neighborhood Park (directly below Waipahu Elementary School). This marsh harbors mostly great bulrush (*Schoenoplectus lacustris*), but parts are overgrown with California grass (*Brachiaria* [=*Urochloa*] *mutica*). The water was only slightly brackish (3 ppt) when water quality measurements were made on January 7. This wetland was revisited on February 3, and additional water testing conducted. The water was found to be somewhat turbid and low in DO: 17 % saturation at 9 AM on January 7 and 31% of saturation at 1125 AM on February 3. Nitrate concentration was low; perhaps not surprising since the vegetation (both bulrush and algae) use up nitrate to promote growth. However, inorganic nitrogen is present here as ammonia. A high total nitrogen content (1280 mg N/l) reflects that nutrient input is probably high, but that most of the inorganic nitrogen has been converted to organic nitrogen by algal productivity. Total P is also very high (503 mg P/l), suggestive again of water quality problems.
>
> Despite the low oxygen, the marsh harbored a large number and variety of aquatic insects, including backswimmers, aquatic beetles, damselfly nymphs, and dragonfly nymphs. Although small numbers of top-minnows (Poeciliidae) were observed, these could not be captured for identification.

> The low DO may suppress fish populations in this marsh, allowing insect numbers to remain high.

The Pūpū'olē Wetlands are coded E2EM1N in the NWI (USFWS, 2007) indicating estuarine features with persistent emergent vegetation. We suggest the correct coding for these features is PEM1F: palustrine, persistent emergent vegetation, semi-permanently flooded.

Miscellaneous Features

A "large sump," partially fenced and described in ACOE (1999, p. 21), is located some 1800 ft (550 m) southwest of the Honouliuli Unit of the Pearl Harbor NWR (see Segment 1). This depression receives runoff from the nearby Lower Village housing development. The depression must function as a sump, as it appears in a satellite photograph (Microsoft Corp., 2006) that no drainages lead out of the roughly 3-acre, well-vegetated area. The bottom of the feature directly off the culvert outlet and 9-12 ft (3-4 m) deep is heavily overgrown with Guinea grass (*Panicum maximum*) and two large umbrella sedge (*Cyperus involucratus*) plants. The remainder is forested with kiawe, koa-haole, monkey pod, and common guava.

Another drainage feature, not connected to the one described above, receives drainage from Lower Village and carries storm run-off northward from a point just outside of the NWR entrance gate (near a Honolulu Board of Water Supply pump station). This ditch is overgrown with hau (*Hibiscus tiliaceus*) and passes through a culvert beneath the C&C bikeway to connect to the wetland we have identified as ID ..3159 (see above).

Tables 2-01 and 2-02 summarize biological observations (fauna and flora, respectively) made in 2006-7 at various wetlands located in the upper East Loch area. Table 2-03 summarizes differences between what was reported for this area as present and surveyed in 1999 (ACOE, 1999) and our 2006-7 observations.

Table 2-01. Aquatic biota listing for wetlands around Hono'uli'uli.

Species listed by family	Common name	Notes	Wetland ID No. ..3159	..3163	..3166	..3167	..3168	..3171	..3178	..3185
	INVERTEBRATES									
MOLLUSCA, GASTROPODA										
PILIIDAE	Apple snails									P

Table 2-01 (continued).

Species listed by family	Common name	Notes	Wetland ID No. 3159	3163	3166	3167	3168	3171	3181	3185
MOLLUSCA, BIVALVIA										
OSTREIDAE										
Crassostrea virginica	Amer. oyster				A					
ARTHROPODA, CRUSTACEA										
CAMBRIDAE										
Procambarus clarki	Amer. crayfish									C
CHTHAMALIDAE										
Chthamalus proteus	Caribbean barnacle				C					
PORTUNIDAE										
Thalamita crenata	swimming crab				U					
ARTHROPODA, INSECTA										
DIPTERA										
CULICIDAE										
Indet.	(mosquito larvae)		A							
ODONATA										
COENAGRIONIDAE										
Ischnura ramburii	Rambur's damselfly								O	
AESHNIDAE										
Anax junius	Green darner			R			U			
LIBELLULIDAE										
Crocothemis servillia	Scarlet skimmer			U	O	U				
Tramea lacerata	Black saddlebags			O						
	VERTEBRATES									
PISCES (fishes)										
CICHLIDAE										
Sarotherodon melanotheron	Black-chin tilapia			A	O			C	A	
GOBIIDAE										
Awaous guamensis	*'o'opu nakea*			R						
POECILIIDAE										
Poecilia mexicana	Mexican molly			A	O			A	A	C
AVES (birds)										
ARDEIDAE										
Bulbucus ibis	*Cattle egret*				C					

Table 2-01 (continued).

Species listed by family	Common name	Notes	Wetland ID No. 3159	3163	3166	3167	3178	3181	3185	3185
CHARADRIIDAE										
Pluvialis fulva	*Kolea*				C					
SCOLOPACIDAE										
Calidris alba	*Hunakai*				U					
Numenius tahitiensis	Bristle-thighed curlew, *kioea*				U					

KEY TO SYMBOLS USED IN TABLE: 2-01

Abundance categories:
R – Rare – only one or two individuals seen.
U – Uncommon – several to a dozen individuals observed.
O – Occasional – regularly encountered, but in small numbers.
C – Common - Seen everywhere, although generally not in large numbers.
A – Abundant – found in large numbers and widely distributed.
P – Present – noted as occurring, but quantitative information lacking.

Table 2-02. Flora listing for Hono'uli'uli, West Loch Shoreline Park and other selected Chapter 2 wetlands.

Species listed by family	Common name	Notes	Wetland ID No. 3159	3163	3167	3168	3178	3179	3180	3181
ACANTHACEAE										
Asystasia gangetica	Chinese violet				U					
AIZOACEAE										
Sesuvium portulacastrum	*'ākulikuli*	(2)							O	
ARECACEAE	(palms)									
Cocos nucifera	*niu*	(1)					U			
Phoenix hybrid	date palm (juv.)	(2)	U							
ASTERACEAE										
Pluchea indica	sourbush	(2)	?	C	O			C	U	C
Pluchea X *fosbergii*	sourbush hybrid	(1)								R
BATACEAE										
Batis maritima	*'ākulikuli kai*			A					A	

Table 2-02 (continued)

Species listed by family	Common name	Notes	Wetland ID No. .3159	.3163	.3167	.3168	.3178	.3179	.3180	.3181
COMMELINACEAE										
Commelina diffusa			**A**		C					
CYPERACEAE	(sedges)									
Bulboschoenus maritimus	*kaluhā*			U						
Cyperus involucratus	umbrella sedge				O					
FABACEAE										
Pithecellobium dulce	*ʻopiuma*	(1)						U		
Prosopis pallida	*kiawe*	(1)					O		O	
Samanea saman	monkeypod	(1)								
MALVACEAE										
Hibiscus tiliaceus	*hau*	(1)	**C**							
Thespesia populnea	*milo*	(1)					O		C	
NYCTAGINACEAE										
Boerhavia coccinea	false *alena*	(1)							U	
POACEAE										
Cenchrus ciliaris	buffel grass	(1)		U						
Chloris radiata	plushgrass	(1)							U	
Cynodon dactylon	Bermuda grass	(1)							C	
Paspalum vaginatum	seashore paspalum								O	
Sporobolis sp.	---	(1)							A	
Stenotaphrum secundatum	St. Augustine grs	(1)							A	
Urochloa maxima	Guinea grass	(1)			C	C		O	U	U
Urochloa mutica	Calif. grass				**A**	A				U
PONTEDARIACEAE										
Eichhornia crassipes	water hyacinth					**A**				
RHIZOPHORACEAE										
Rhizophora mangle	red mangrove			**A**				**A**	**A**	**A**

Notes:

(1) Typically not a vegetation of wetland, but growing around margin.
(2) Marginal vegetation member; more typically growing close to wetland.

Table 2-03. Summary of Changes since 1999

Site	Description	Change since 1999	ACOE ID
South end of ID ..3163	Depression with a small palustrine wetland.	Distinctive from ID ,,3163; a palustrine feature.	**..3159**
Pond surrounded by *Batis* flat		No change	**..3163**
Four ponds south of Hono'uli'uli Stream mouth	Overgrown with mangrove.	No change.	**..3160, ..3161 ..3162, ..3178**
Mangrove at mouth of Hono'uli'uli Stream and south along shore	Stream channel through mangal	No change	**..3166, ..3177 ..3179**
Ka'auku'u Fishpond	Heavily overgrown with mangrove. Some open water remaining.	Less open water present.	**..3181**
West Loch Shoreline Park	Mangrove, some areas of *Batis*.	Some expansion of mangrove; but C&C removing mangroves along the park shore.	none
Hono'uli'uli Estuary	Channel lined with mangrove.	No change	**..3175, ..3176 ..3177**
Hono'uli'uli Stream	Palustrine wetland overgrown with California grass.	No change.	**..3172, ..3174 ..3177**
Golf Course Water supply reservoir & driving range.	Wetland	Not a wetland.	..3182
West Loch Golf Course ponds/ water traps	Wetlands	Ponds; most do have non-jurisdictional wetland margins.	..3168, ..3169 ..3171, ..3173 ..3183
Former Kahua Meat Co. Pond	Pond utilized for treating wash-down effluent.	Filled in.	..3167
Laulaunui Islet and fishpond	All low areas overgrown with mangrove.	No change.	**..3186 through ..3196**
Private *kalo lo'i*	Spring-fed pond with taro.	Stocked with ornamentals.	**..3185**

Table 2-03 (continued).

Site	Description	Change since 1999	ACOE ID No.
West Loch north shore mangrove	Extensive mangal around old fishpond.	No change.	**..3219, ..3220**
Pūpū'olē wetland	Depressional wetlands.	Nearly choked with California grass.	**..3217, ..3218**
West Loch north shore mangrove	Extensive mangal at mouth of Waikele Stream.	Further expansion of mangroves into West Loch; coalescence of numerous small clusters off stream mouth.	**..3223 through..3230, ..3239, ..3240**

Note: ID numbers in bold are jurisdictional wetlands; others are not.

Following are supplemental photographs (SP) for Chapter 2.

SP2-01 (left): Remnant of open water in mangrove infested Ka'auku'u fishpond (..3181) at West Loch Shoreline Park.

SP2-02 (left): Remains of a concrete *makahā* that once connected Ka'auku'u pond to West Loch via a channel that no longer exists.

SP2-03 (left). Tidal water rushing through the mangrove-blocked channel connecting the lower end of Hono'uli'uli Stream (..3177) and a series of former ponds to the south (..3178 and beyond).

SP2-04 (left): Pond feature at wetland ID ..3163 with pickleweed flat at north end showing invasion underway by mangrove. Gray material along pond shore is an algal scum floating on water surface.

SP2-05 (left): Golf Course Pond (ID ..3168) completely covered by water hyacinth, a floating plant and therefore treated under ACOE rules as open water, not wetland.

Chapter 3
Waipi'o Peninsula

The Waipi'o Peninsula is an interfluvial remnant between the lower valleys cut by Waikele and Hono'uli'uli streams on the west (flooded by West Loch) and Waiawa Stream and its tributaries on the east (flooded by Middle Loch). The topography of the Peninsula is complicated by a transverse cut that forms narrow Walker Bay midway down the 3.3 mi (5.3 km) long peninsula. Although various areas have been built up with fill, the feature is not man-made from fill, only that several former shallows have been "reclaimed" for various purposes. The area encompassed in this chapter corresponds closely to ACOE (1999) Segment 4.

Waikele and Kapakahi Streams

A second, eastern outlet of the Waikele Stream (see Chap 2) floodway is called Kapakahi Stream, the lower, mangrove-choked portion of which was identified (ACOE, 1999) as ID ..4243. This estuary is confined by levees to a narrow canal running along the west side of Waipahu Depot Street. The banks are steep and clearing of mangrove and brush was occurring in 2006 within the channel and along both banks. By the end of 2006, mangroves (except for widely scattered seedlings) were no longer present here or in a side channel leading eastward and serving as a drain for the C&C, former waste incinerator site. A second, much smaller side branch is located opposite the C&C Police Academy (Ke Kula Maka'i) that drains that site to Kapakahi channel. This area is interesting because it presently supports a wide variety of wetland plants, including *kaluhā* (*Bolboschoenus maritimus*), *'ae'ae* (*Bacopa monnieri*), seashore paspalum (*Paspalum vaginatum*), Indian sourbush (*Pluchea indica*), sedge (*Cyperus polystachyos*), and a few mangrove seedlings, all within a very small area (*AECOS*, 2007).

The channel of Kapakahi extends well into the coastal mangroves of West Loch, and is bermed, isolating fresh or brackish flows from adjacent Po'uhala Marsh (Ducks Unlimited, 1998; Englund et al., 2000). Englund et al. (2000) found that the salinity in West Loch fronting the mangroves off Kapakahi channel was only 9 ppt, but 36 ppt further out in the Loch. Salinities upstream of the coastal mangrove belt were 0 ppt. Upstream, a spring located just north of Farrington Highway and emerging underneath Shiro's Food parking lot feeds the stream through a thick stand of mangrove (Nance, 1998).

The main channel of Waikele Stream enters West Loch further west (Fig. 3-01 and 3-02). The channels of the streams are estuarine at the old railroad right-of-way. Both streams are presently crossed by rusting, iron bridges that carry petroleum products pipelines (part of the energy corridor) and limited to foot traffic only. This section of the corridor, all the way to the north gate at West Loch Shoreline Park (see Chap. 2) is not yet developed as a bikeway, although some improvements have been made at Po'uhala Marsh to accommodate school and other visitor groups.

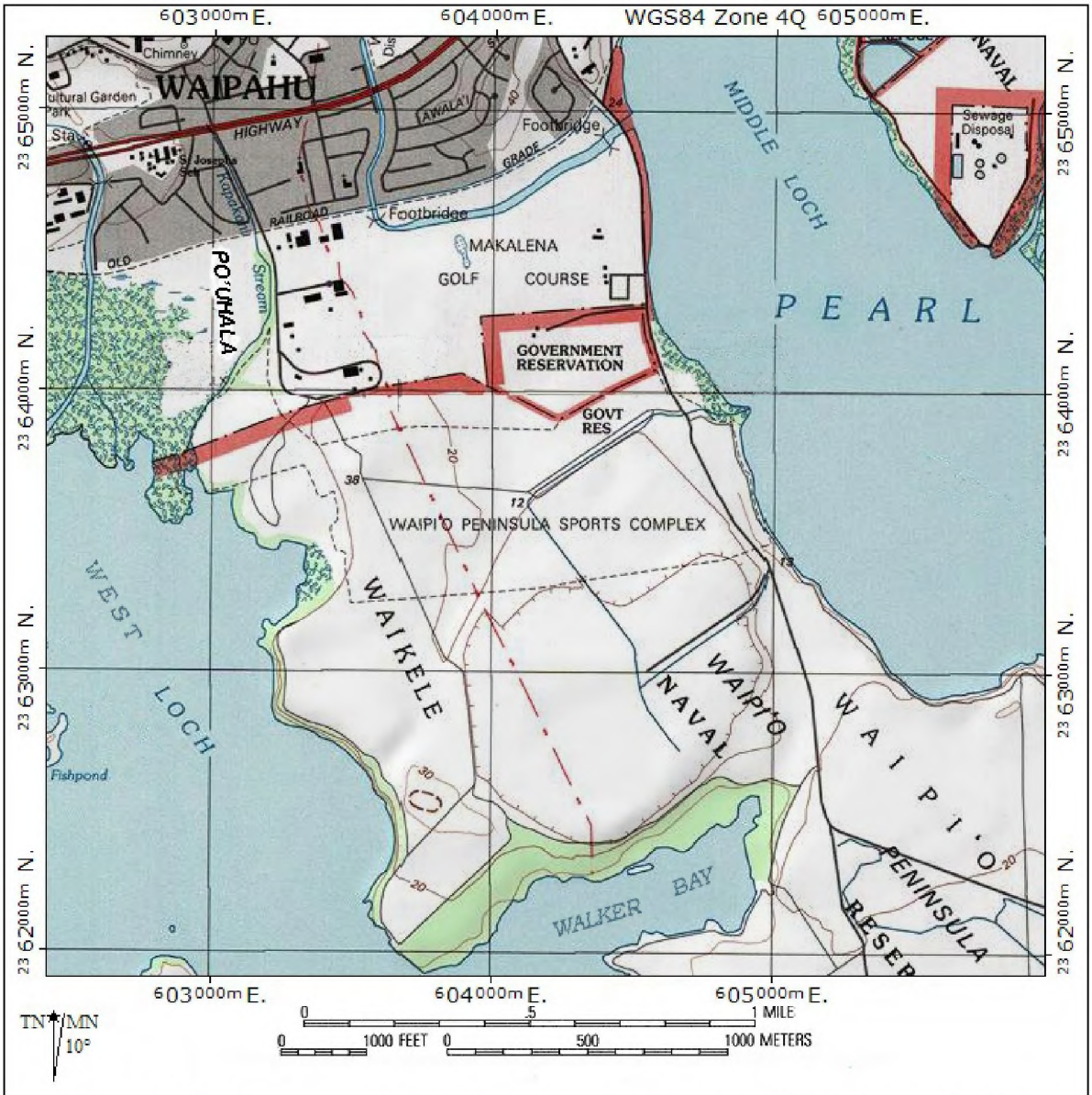


Figure 3-01. Upper half of Waipi'o Peninsula from Waipahu to Walker Bay

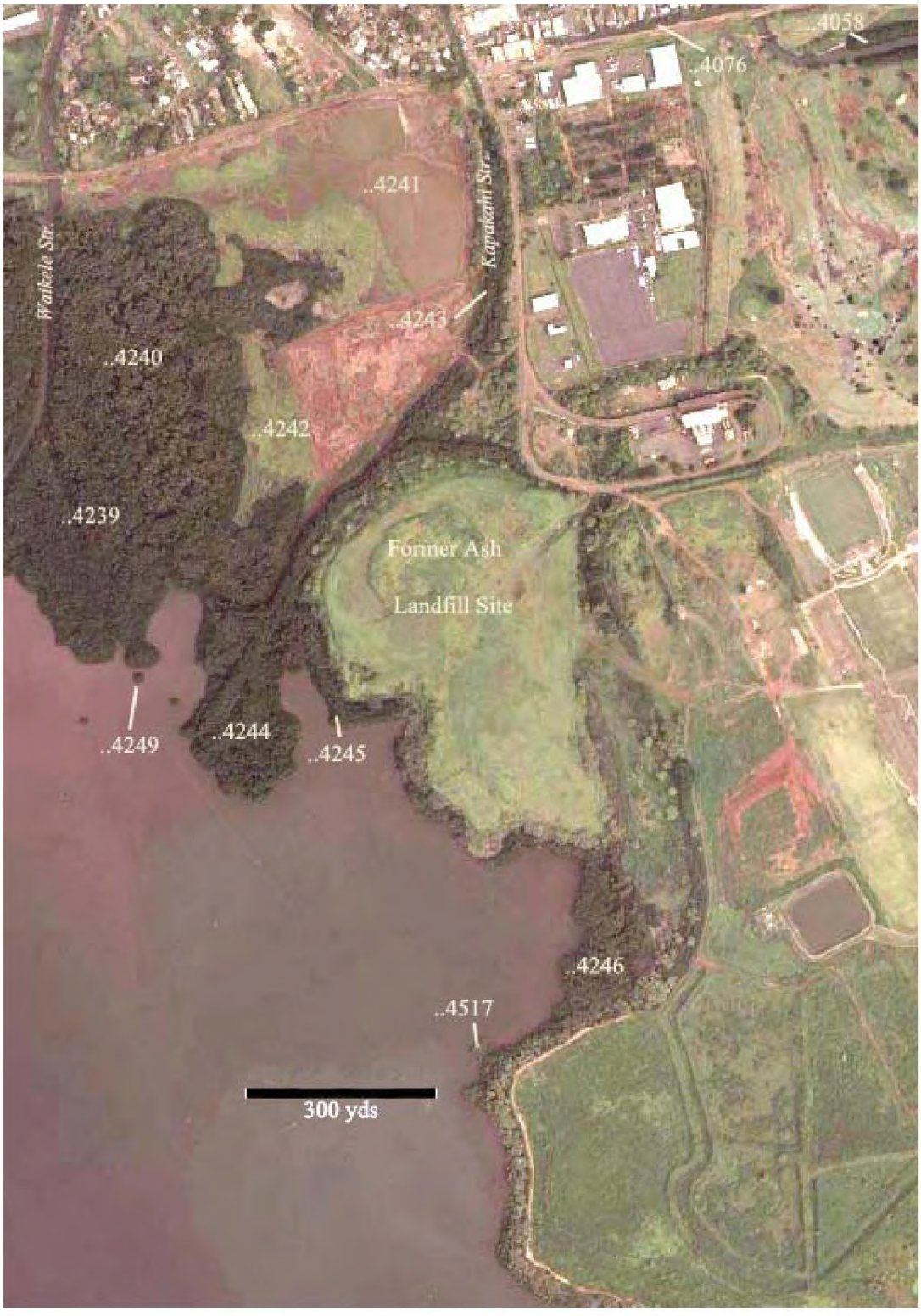


Figure 3-02. Satellite image of West Loch and upper west side of Waipi'o Peninsula in the vicinity of Po'uhala Marsh showing ACOE wetlands.

Po'uhala Marsh

Po'uhala Marsh (ID ..4241) is a saline wetland dominated by pickleweed (*Batis maritima*), but with expansive shallow, open water areas conducive to utilization by Hawaiian stilt (see photo SP3-03). It is the remnant of an extensive tidal flat that has, in the last 50 years, become nearly isolated from West Loch by a mangrove forest (IDs ..3221, ..4239-..4240, ..4244; see Chap. 2) and by man-made levees and fill. The marsh and a former fishpond together totaled 70 ac (28 ha), of which only 24 ac (10 ha) is marsh useful to waterbirds. Much of the remainder has been filled (8 ac or 3 ha) or overgrown by mangrove (38 ac or 15 ha; Ducks Unlimited, 1998). A large part of the marsh was degraded by solid waste disposal activities over a long period of time, and although dump sites are still present (Photo 3-03), a major clean-up of the area several years previously has greatly improved conditions in the wetland.

Figure 3-03. Portion of the northern shore of Po'uhala Marsh (*mauka* marsh) with old bottle dump area exposed on mud flat. *Kiawe* trees in background line the levee separating Kapakahi Stream from the marsh, but the trees were removed in 2007.

Because of it's importance to endangered waterbirds, extensive studies have been done in Po'uhala Marsh including detailed surface contour surveys, soil borings and soil contaminants, water quality, biology, and pieziometer (water level) studies for a marsh enhancement plan and environmental assessment (Ducks Unlimited, 1998). Biological studies included flora and fauna (Arthropoda and Aves) surveys. Vegetation of the marsh is described by Nishida and Imada (1997). A map depicting vegetation types and open water areas produced by Ducks Unlimited is reproduced herein as Fig. 3-04. The map shows only the border of the mangrove swamp that extends solidly to the channel of Waikele Stream to the west (see Fig. 3-02). The marsh is divided into two areas by a triangular parcel of ruderal (fill) land along Kapakahi Stream: an upper or *mauka* marsh (ID ..4241), and a lower or *makai* marsh (ID ..4242). The *mauka* marsh is a playa, with large areas of open water and barren mud flats covering the eastern half (see Fig. 3-03). Playas are characterized by seasonal declines in water level that result in salt pans with a powdery sediment that blows away, retaining the basin shape. This wetland type is dependent upon the capture of saline (Pearl Harbor) water as a source of salt Salinity at the inland (northern) end was 82 ppt on 09/19/06, or about 2.4 times sea water salt content.

The NWI maps for the area around Po'uhala Marsh designate the mangal around Waikele Stream mouth and south of the marsh as E2FO3N: estuarine, intertidal, regularly flooded, broad-leaved evergreen forest (i.e., mangrove). The more interior part of the area is put in the category E2EM1P: Estuarine, intertidal, irregularly flooded, emergent marsh, for the pickleweed tidal flat and playa. Pickleweed is small shrub, and therefore the correct classification would be E2SS3P. The most interior part is given the coding PEM1F: Palustrine, semipermanently flooded persistent emergent marsh. Although this classification may be correct for a small portion of Po'uhala Marsh, this type is not shown on the Ducks Unlimited map (our Fig. 3-04) and the NWI mapping is not accurate (indicating the playa). Nearly all of the marsh is either pickleweed flat, open water, or exposed mud flat. However, in the northwestern corner there is a small area with distinct vegetation indicative of freshwater intrusion and palustrine ecology. The same or a similar area is described by Englund et al. (2000, p. 22):

> A large spring area was observed to issue from the center of Pouhala Marsh, and salinity was measured at 1 ppt near an area of clear water in the center of the marsh; the marsh at this freshwater spring area was dominated by the introduced common cattail (*Typha latifolia*). During our fieldwork, the marsh area also contained several other areas of open water with salinities of 8 to 9 ppt.

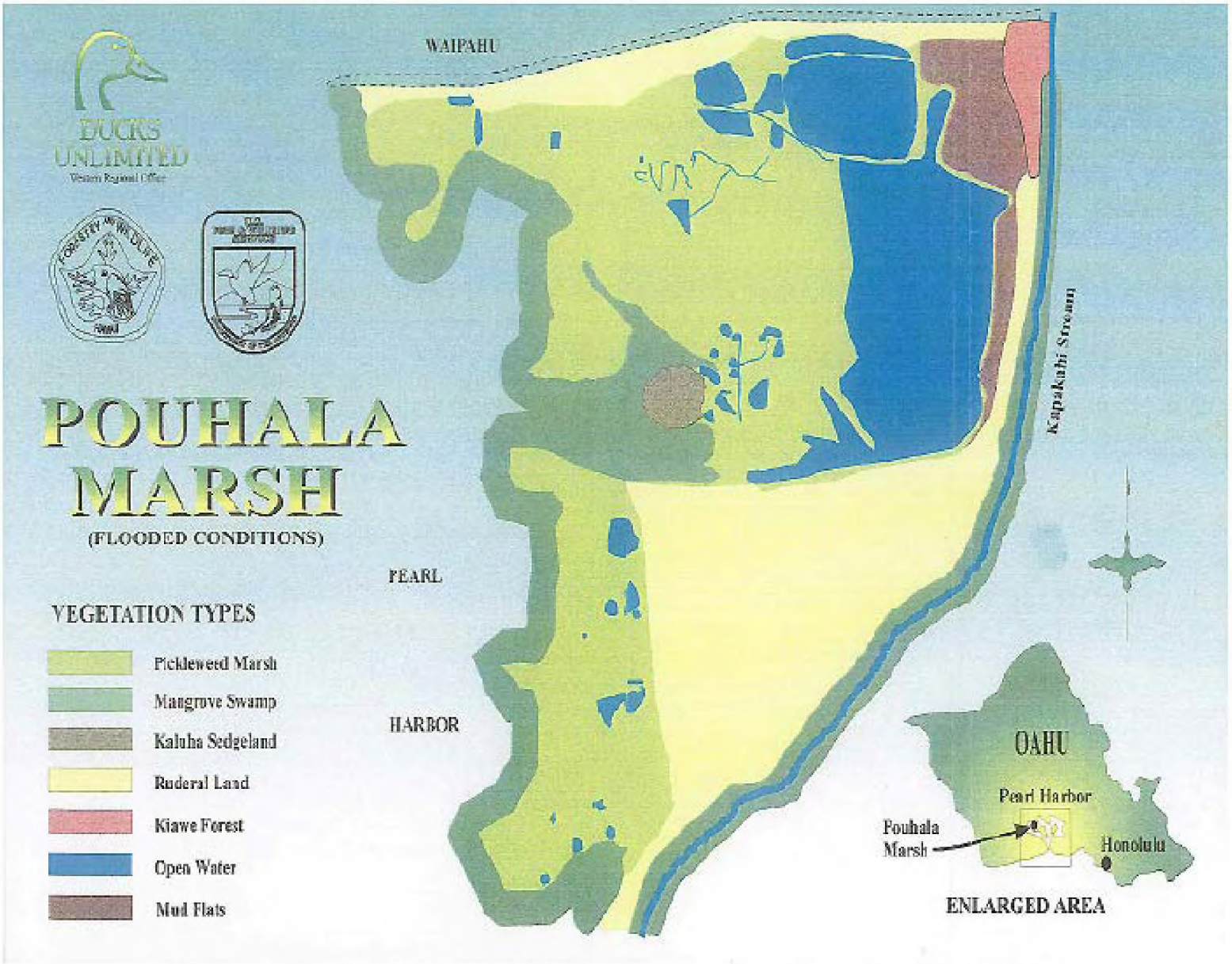


Figure 3-04. Po'uhala Marsh vegetation map (from Ducks Unlimited, 1998).

Table 3-01. Reported waterbird species of Po'uhala Marsh (from Ducks Unlimited, 1998)

Species	Occurrence in Hawai'i		Status on Po'uhala Marsh
Ardeidae			
Black-crowned Night-Heron	Indigenous	Resident	Common
Cattle Egret	Introduced	Resident	Common
Little Blue Heron	Accidental		Three records
Anatidae			
Hawaiian Duck (Koloa)	Endemic	Endangered	Very Rare - hybrids pose problem
Mallard x Koloa	Hybrid Species		Rare
Northern Shoveler	Migratory		Uncommon Winter Visitor
Northern Pintail	Migratory		Uncommon Winter Visitor
Rallidae			
Hawaiian Coot	Endemic	Endangered	Hypothetical Occurrence
Hawaiian Moorhen	Endemic	Endangered	Rare breeder
Recurvirostridae			
Hawaiian Stilt	Endemic	Endangered	Common resident, rare breeder
Charadriidae			
Pacific Golden-Plover	Migratory		Common Winter Visitor
Black-bellied Plover	Migratory		Rare Winter Visitor
Semipalmated Plover	Migratory		<5 records
Scolopacidae			
Bristle-thighed Curlew	Migratory	Sensitive	Rare Fall Transient
Greater Yellowlegs	Migratory		1 record
Wandering Tattler	Migratory		Uncommon Winter Visitor
Ruddy Tumstone	Migratory		Uncommon Winter Visitor
Sanderling	Migratory		Rare Winter Visitor
Western Sandpiper	Migratory		1 record
Least Sandpiper	Migratory		2 records
Ruff	Migratory		2 records
Long-billed Dowitcher	Migratory		< 5 records
Wilson's Phalarope	Migratory		1 record

Table taken from Ducks Unlimited (2000): assembled from the following sources: Rare Birds DataBase (Bishop Museum), DOFAW biannual waterbird survey results 1940 - 1996, A. Engilis, Jr. (1988), A. J. McCafferty pers obs., and P. Donaldson (pers obs.).

West Loch, East Shore

In addition to the mangrove forests that cover the stream deltas extending into West Loch from the mouths of Waikele and Kapakahi streams (Fig. 3-02), a

narrow mangrove belt exists along the shore of the old ash landfill southeast of Po'uhala Marsh. This particular wetland (ID ..4245, por. of ..4246) was delineated by Guinther in 2001 (*AECOS*, 2001a):

> ...[T}he definition of jurisdictional waters in 33 CFR 328 includes "all waters subject to the ebb and flow of the tide." In tidal waters, jurisdiction extends to the high tide line, defined as (33 CFR 328.3.d) "...the line of intersection of the land with the water's surface at the maximum height reached by a rising tide." Wetlands delineation by ACOE (1987) applies only to a subset of waters of the United States. Jurisdiction in tidal waters is independent of vegetation and soil type. Because, the Waipahu Ash Landfill site is located on tidal Pearl Harbor, the delineation of the wetland boundary can be established as the high tide line. In most areas around the south and west shore, this boundary is readily discerned in the field because the face of the fill is relatively steep and descends steeply into the intertidal zone (that is, the wetland boundary lies within 0.5 m (1.6 ft) of the intersect between the fill and the vegetated salt flat. Despite the presence of obligate wetland vegetation (*Batis maritima* or pickleweed and overhanging *Rhizophora mangle* or mangrove) approaching 100% cover on slopes above the high tide line, these areas are nearly everywhere characterized by fill debris (usually ash containing metal and glass inclusions) that does not qualify as hydric soil.
>
> Other areas within or adjacent to the project site, especially on the northwest, proved to be less straight-forward because extensive areas of *B. maritima* surround shallow ponds on low-lying ground (Figure [3-05]). Nonetheless, after thorough exploration it was decided that what appeared to be isolated pools were in fact tidal, and a similar reasoning could therefore be applied to delineate the wetland boundary. Note that it is only in the area west and southwest of the project site that the proposed limit of construction extends into jurisdictional waters. These areas are mostly where mangrove has encroached on shallow placed fill, and where it is intended to excavate ash material for return to the interior of the landfill before capping (Earth Tech, 1999b).

South of the old ash landfill, the mangrove forest (ID ..4246) broadens to about 375 ft (115 m), then narrows again as the shoreline turns roughly southwestward. The mangrove ends more or less where the shoreline turns southward. A small mangrove cluster off the west end is numbered ..4517 on one map and ..4284 on another (ACOE, 1999).

ACOE (1999) does not address this area, except to note as we have that the mangrove forest (ID ..4246) at the mouth of this depression is part of the coastal mangrove belt extending south from Kapakahi Stream. However, the

NAVMAG Pearl Harbor INRMP (NAVFACENGCOM, 2001, p. 3-21) contains this statement presumably pertaining to the same depression (and located correctly on their Fig. 3-6):

> California grass...forms a swampy [sic] meadow behind the mangrove forest located near the sanitary landfill.

Figure 3-05. An area on the northwest boundary of the ash landfill site near Station 11 (*AECOS*, 2001a) characterized by a pickleweed (*Batis maritima*) flat with open pools (part of ID ..4244). Old landfill slope is evident in background left.

Further, Whistler (1998) describes "a low, shallow, trough-like area that extends from the landfill area down to the mangroves by [West Loch] at the south end of which is a freshwater marsh." Whistler's description is a bit tentative: "Still further south [along this depression]... the soil apparently becomes moister, and the vegetation changes [from California grass] to a freshwater marsh." The flora, described as patchy over the area, consists of elephant grass, umbrella sedge, Indian pluchea, moon flower (*Ipomoea alba*), California grass, and ivy gourd (*Coccinea grandis*), several species being indicative of a wetland. This report was an appendix to the Soccer Park EIS (Belt Collins Hawaii, 1998) which states (p. 3-16 & 3-18):

> Three possible wetland areas on or next to the soccer park site were identified during the February 1998 [i.e., Whistler] survey: (1) Pickleweed Marsh; (2) Freshwater Marsh; and (3) Mangrove Swamp... However, a subsequent wetlands survey indicated none of the three sites meet the U.S. Army Corps of Engineers criteria for hydric soils [cited as a footnote: ACOE, 1987]. Therefore, there are no wetlands within the proposed project area.

No information is given as to what the "subsequent survey" was; however, for the "Freshwater Marsh," if true (no hydric soil present), the site would not be a jurisdictional wetland. For the mangrove and pickleweed areas, ACOE jurisdiction likely does still apply—both species are obligates and usually indicative of tidal inundation—and wetlands are (or were), in fact, present (see *AECOS*, 2001a for a subsequent delineation of some of these areas, although that document does not really address the described freshwater marsh location). There exists a depression here, presumably a remnant of the old shoreline that was not completely filled but was cut off from West Loch by landfill activities.

A "wetland" PUBKrx (Palustrine unconsolidated bottom, artificially flooded, artificial substrate, excavated) immediately east of the depression described in the previous section is present as a single treatment lagoon of some sort. This feature was apparently built at the same time as the soccer park and does not appear on the ACOE (1999) aerial photographs, but is shown as on the NWI map (USFWS, 2007) and can be seen in Fig. 3-02 near the lower right corner. Man-made waste treatment ponds are non-jurisdictional.

Oahu Sugar Settling Ponds

A large part of the Waipi'o Peninsula was, until 1992, devoted to sugar cane cultivation and disposal of sugar mill processing water into ponds built behind a series of dikes. In that year, Oahu Sugar ceased operating, fields were abandoned, and sugar mill water was no longer piped to the settling ponds which had become wetlands, significant for waterbird use (Ducks Unlimited, 1998). After 1992, the wetlands rather quickly dried up (ACOE, 1999) and much of the area of former ponds is now a City & County Soccer Park. When visited by the ACOE biologists, some hydric vegetation was still present, but the area was declared non-wetland by virtue of lacking hydrology (ACOE, 1999). Pond basins not yet obliterated are located on Navy property south of the soccer park.

A number of different wetland features are indicated on NWI maps (USFWS, 1999, 2007) covering the interior of the upper Waipi'o Peninsula. A palustrine, scrub-covered wetland (PSS1/EM1C) shown on the NWI maps (USFWS, 1999)

to the south of the old City & County landfill and inland (southeast) of the mangrove at ID ..4246 is separated from the mangrove by a high berm. USFWS (2007) presents a far more complex picture of aquatic features in this location with most of the depression shown as upland, except the southern tip coded PUSKx and another pond just north coded PSS3Kx. A ditch, coded PEM1Cx, follows the entire western outline of the 1999 feature. A ditch across (on the east side of) Waipahu Depot Road is coded R2UBKx (riverine, lower perennial, unconsolidated bottom, artificially flooded, excavated) and two small pond features are coded PSS3Cx and PUBFx. These are all man-made, excavated features (coding "x") with various vegetation types (or bare of vegetation), and water regimes supposedly ranging from seasonal to artificially flooded to semipermanently flooded ("F") in one case. The "perennial riverine" coding would seem incorrect. This is a dry area of abandoned, man-made ditches and retention basins lacking any source of water other than direct rainfall. The area has changed greatly over the last two decades as discussed above, and the 1999 designations are now certainly irrelevant. The complex coding applied to various man-made ponds and drainage ditches that are nearly always dry (USFWS, 2007) would seem also irrelevant to jurisdictional wetlands considerations.

The NWI (USFWS, 2007) shows several other features further to the south and east that also may be related to the settling ponds and or former agricultural activities. A ditch system coded PEM1Kx (wetland in an artificially flooded, excavated ditch) is shown draining to a pond coded PSS3Kh (an artificially flooded, diked impoundment supporting broad-leaved evergreen scrub-shrub). We found a water-filled ditch dug out several meters below the land surface along the road at the northeast end of the bay. The NWI codes a corresponding feature as PUBHh (palustrine, unconsolidated bottom, permanently flooded diked/impounded) in this area.

The situation is somewhat more complicated around Walker Bay (see below) where the drainage features are basins located closer to Pearl Harbor and closer to sea level.

Walker Bay

Walker Bay is a narrow re-entrant of West Loch partially dividing the Waipi'o Peninsula. The Bay (Fig. 3-06) is nearly completely surrounded by mangal, only the south shore, where the mangrove border is narrow and broken, affording access to the water without great effort. The northern shore is complicated. Mangal lines the inner, north shore to such an extent (ID ..4068, ..4069, ..4071, and ..4072) that the view of Walker Bay is all but obscured from anywhere on the north side. However, behind this mangal are open areas of *Batis* (Fig. 3-07; ID ..4070) and various drainage (or perhaps detention) features that contain

water in some cases, and are playa-like features in others (Fig. 3-08; ID ..4067 and others not identified in 1999; see photo SP3-02). These depressions, which have high, steep sides, were presumably built to capture and infiltrate runoff from upland sugar cane fields.

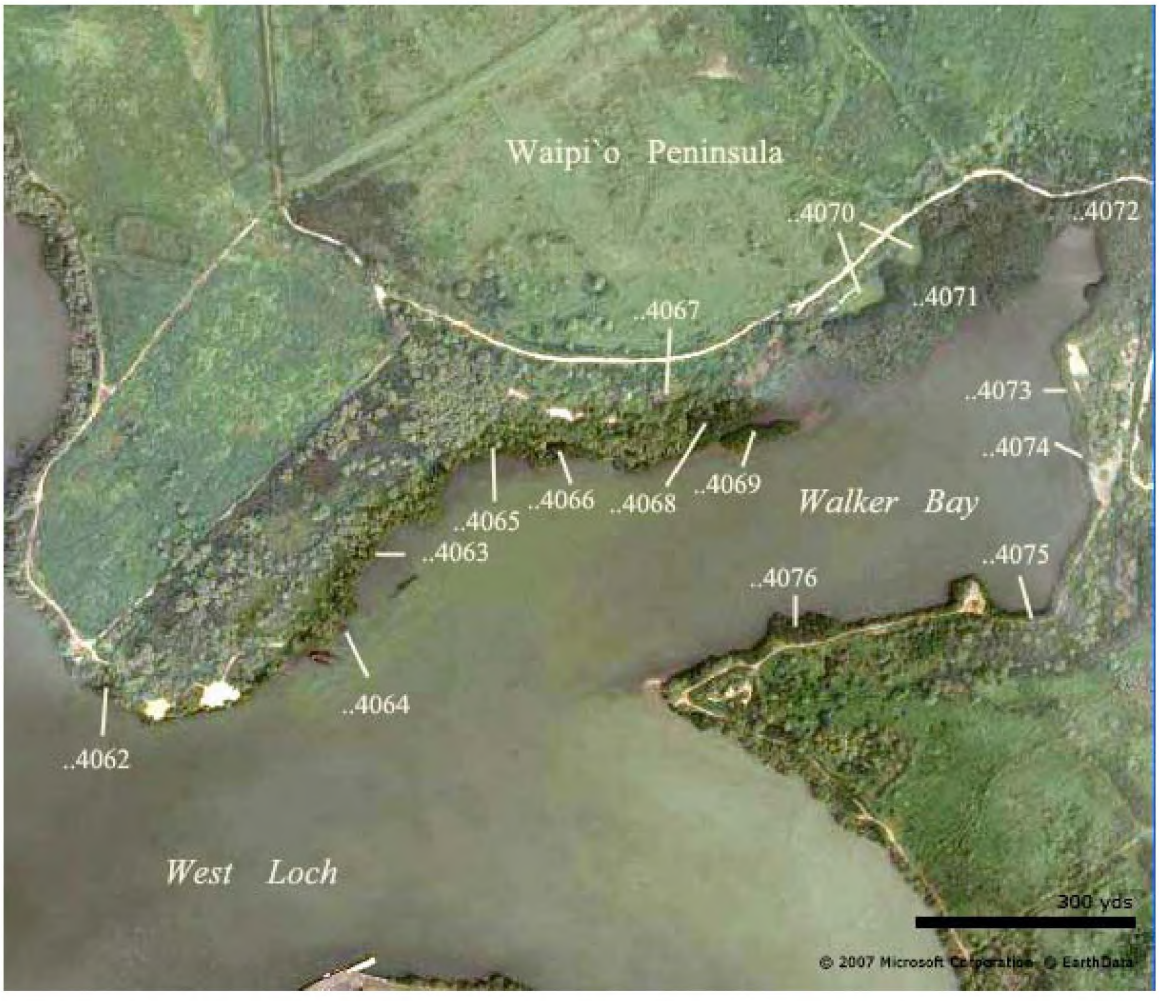


Figure 3-06. Satellite image of Walker Bay showing ACOE (1999) numbered wetlands.

The basins demonstrate an important aspect of playa features: an absence of vegetation of any kind in the central or lowest part(s) of the depression (Fig. 3-08). Here, *Batis* grows away from the central depression, which is barren of vegetation for the reason that after flooding, water slowly evaporates, concentrating salts in an increasingly smaller pool area. Eventually the concentration exceeds that which *Batis* and all other plant can endure. Although clearly isolated, basins having this configuration of a barren flat surrounded by pickleweed are ephemeral, saline wetlands. The NWI (2007)

shows the multiple basins incorrectly (the basins are separated by high berms) as a single long wetland feature coded E2EM1/SS3N (estuarine intertidal with persistent emergent vegetation and broad-leaved evergreen scrub-shrub, regularly flooded). This coding does not fit and we would code at least some of the basins (not all are wetlands) E2SS3J1: estuarine, intertidal broad-leaved evergreen scrub-shrub, intermittently flooded, hyperhaline (or could be seasonally flooded).

Figure 3-07. A *Batis* wetland (ID ..4070) behind dense mangal (ID ..4071) at Walker Bay.

The *Batis* flat (ID..4070) behind the mangal is irregularly flooded, but potentially connected to the mangal (ID..4071) and, by extension, connected to Walker Bay. The isolated depressions (ID ..4067 is an example) are not easily regarded as jurisdictional wetlands. The basins are completely cutoff from tidal incursion by high berms and appear to accumulate water only via direct rainfall. But if that were the entire situation, the bottoms of the basins would support more vegetation and not less vegetation than the surrounding uplands. There must be a source of salt that is being concentrated in the depression, and presumably this source is brackish or saline groundwater. The salts become

concentrated because fresh water rainfall, or run-off water that enters during storms, leaves the basin largely by evaporation.

The NWI (2007) indicates several wetlands along the north shore of the Bay. These are designated E2FO3N (Estuarine intertidal, regularly flooded, broad-leaved evergreen forest; i.e., mangal), with a small area of E2SS3N (estuarine intertidal regularly flooded, broad-leaved evergreen scrub-shrub) on the east, presumably indicating less developed mangrove forest. The *Batis* flat just inland (Fig. 3-07) is incorrectly coded E2EM1N, and should be E2SS1P (estuarine intertidal, irregularly flooded, broad-leaved evergreen scrub-shrub; i.e., a "high" *Batis* flat).

Figure 3-08. A playa feature inland of Walker Bay. Note that *Batis* grows away from the central depression, which is bare of vegetation (and salt encrusted) indicating this is an ephemeral, saline wetland. Also, note the steep basin wall covered in dry grasses.

As noted elsewhere, the designation E2SS3N fits where young mangrove plants are shrubs just colonizing an area, but is not an especially useful distinction for mangrove growth because these shrubs grow into trees as the mangal develops. The classification code E2SS3N can also fit an intertidal, *Batis* flat, since

pickleweed is a woody shrub. While there certainly are parts of a mature mangal where surface water floods only infrequently (and therefore the designation "irregularly flooded" would be appropriate), most of the narrow to moderately broad (from low tide to high tide line) mangrove formations around Pearl Harbor are completely flooded on a regular basis by the tide. Application of regularly and irregularly flooded codes to these features is discussed further on page 21.

Peninsula South of Walker Bay

South of Walker Bay, the Peninsula narrows to Waipi'o Point at the southern tip. Some of this area was leased for farming in the past, and drainage ditches are present, some near the shore supporting "wetland" vegetation such as *Batis* and *Pluchea* (Fig. 3-09). A few scattered wetlands appear on the NWI maps

Figure 3-09. Drainage ditch inland of the south shore of Walker Bay.

(USFWS, 2007), being mostly agricultural detention ponds (PEM1Ch,EM1/SS3Ch, PEM1Fhd, and PFO3Ch) and drainage ditches (PEM1Cx). Two large features at the end of the peninsula are coded PUSCx (palustrine, unconsolidated shore, seasonally flooded, excavated) and L2USAx with L2USCx

in its interior: a man-made lake with an unconsolidated shore that is seasonally flooded in the middle and temporarily flooded around the margins. Both of these features are large, soil-diked detention ponds, and are best both coded L2US2Chx. The more northern feature is older and has developed some vegetation, which may be the reason it is coded as a palustrine feature, but it is likely that this vegetation is dominated by weeds growing after the water recedes rather than "emergent wetland plants." Neither is a jurisdictional wetland.

Middle Loch, West Shore

An inlet or inland depression with a wetland (ID ..4057) is shown north of the degaussing station (NWI: E2FO3N surrounded by E2SS3N and some E2FO3P). This feature was not investigated.

Much of the east shore of Waipi'o Peninsula (Middle Loch west shore) is lined with a thin, broken stand of red mangrove from the U.S. Navy degaussing station north to the U.S. Navy Ship Facility. The most significant area of mangal occurs just south of the latter (ID ..4052 and ..4288). Wetland ID ..4288 was investigated in 2007. This mangrove area is complicated and appears to be part of drainage system and/or detention basin since abandoned, but still receiving runoff from adjacent roads (Waipio Point Access Rd. near entrance to Waipio Soccer Park).

Kahu Drainage Channel ~ The Kahu Drainage Channel conducts runoff from Wailani Stream draining the eastern half of Waipahu and parts of Waikele/Crestview into Middle Loch of Pearl Harbor (*AECOS*, 1988). This drainage is referred to as E'o Stream by Englund et al. (2000), while admitting the channel is man-made from draining and filling of the former E'o Fishpond on Middle Loch. Lands further *mauka* drain to the east (Panakauahi Gulch) or west (Kipapa Gulch). The Kahu Channel is essentially a concrete drainage canal at sea level; water flow is typically sluggish and basically estuarine and tidal much of the time. The channel reaches the Waipi'o Peninsula midway across the peninsular base, then turns eastward after it enters the City & County of Honolulu, Ted Makalena Golf Course. Upstream and through the bend, Kahu Channel is lined with vertical concrete walls (*AECOS*, 1988) and water salinity has been measured at 13 ppt (Englund et al., 2000). The channel widens through a revetment-lined section, then is contained in soil banks. From this point, about 150 ft (50 m) downstream of the bend, the channel is lined with a dense band of red mangrove trees (ID ..4058, ..4059, and ..4061) to the channel mouth at Middle Loch. Near where Waipio Point Access Road crosses this channel, conditions are generally marine, with a hard-bottom of coral rubble present and a water salinity of 35 ppt (Englund et al., 2000).

The mangrove belts are coded E2SS3N: estuarine intertidal regularly flooded, broad-leaved evergreen scrub-shrub (USFWS, 2007).

Smaller canals (ID ..4076, ..4077, and ..4079) drain into the Kahu Channel from the east and west on the *mauka* (north) side of the old railroad right-of-way (Fig. 3-02; *AECOS*, 2005), now the energy corridor and a developed jogging path and bikeway between Waipahu Depot Road and Waipi'o Point Access Road (*AECOS*, 2000). These ditches are lined in places by very narrow groupings of mangroves growing on on the banks, which were seen to have been recently cleared at the west end (ID ..4076) of the channel located opposite the C&C Fire Truck Repair Facility. The fact that only a delayed maintenance schedule represents the difference between these man-made urban drainage channels being wetlands or not is problematic from an inventory perspective. The waters are tidal, so jurisdictional issues are independent of their wetland status. The banks are not hydric soils, although the channel bottoms would seem to typically contain anoxic sediments, the more so when clogged by mangrove growth. And, of course, mangrove is an obligate wetland species.

ACOE (1999) marked as wetland ID ..4060, the water hazard or pond at the Ted Makalena Golf Course, but did not discuss this feature in their report. This water feature is coded PEM1Cx (west side) and PUBHx (open water) in the NWI (USFWS, 2007); that is, an excavated palustrine feature that is partly permanently flooded and partly seasonally flooded, the latter supporting emergent vegetation.

Middle Loch, North and East Shores

Eastward, beyond the mouth of Kahu Drainage Channel ("E'o Stream") is the mangrove-lined north shore of Middle Loch (Chap. 4). It is along this coast that several high volume Pearl Harbor area springs discharge into Pearl Harbor, contributing to palustrine wetland features behind the shore.

Tables 3-02 and 3-03 summarize biological observations (fauna and flora, respectively) made in 2006-7 at various wetlands located in the upper East Loch area. Table 3-04 summarizes differences between what was reported for this area as present and surveyed in 1999 (ACOE, 1999) and our 2006-7 observations.

Table 3-02. Aquatic biota listing for upper West Loch wetlands.

Species listed by family	Common name	Notes	Wetland ID No. 44076	44024	44241	44243
	INVERTEBRATES					
ARTHROPODA, CRUSTACEA						
PORTUNIDAE						
Thalamita crenata						R
ARTHROPODA, INSECTA						
ODONATA						
AESHNIDAE						
Anax junius	Green darner		R			R
LIBELLULIDAE						
Tramea lacerata	Black saddlebags					R
COENAGRIONIDAE						
Ischnura ramburii	Rambur's damselfly			R		
	VERTEBRATES					
PISCES (fishes)						
CICHLIDAE						
Cichlisoma nigrotasciatum	Convict cichlid					O
Sarotherodon melanotheron	Black-chin tilapia		A		A	C
MUGILIDAE						
Mugil cephalis	*ʻamaʻama*		A			
POECILIIDAE						
Poecilia mexicana	Mexican molly		A	C		C
AVES (birds)						
ARDEIDAE						
Bulbucus ibis	*Cattle egret*				R	
RECURVIROSTRIDAE						
Himantopus mexicanus knudseni	*Aeʻo*				C	A
SCOLOPACIDAE						
Calidris alba	*hunakai*				U	

KEY TO SYMBOLS USED IN TABLE: 3-02

Abundance categories:
R – Rare – only one or two individuals seen.
U – Uncommon – several to a dozen individuals observed.
O – Occasional – regularly encountered, but in small numbers.
C – Common - Seen everywhere, although generally not in large numbers.
A – Abundant – found in large numbers and widely distributed.
P – Present – noted as occurring, but quantitative information lacking.

Table 3-03. Flora listing for Hono'uli'uli, West Loch Shoreline Park and other selected Chapter 2 wetlands.

Species listed by family	Common name	Notes	Wetland ID No. 3217 (a)	4067	4074	4241 (b)
AIZOACEAE						
Sesuvium portulacastrum	*'ākulikuli*	(2)				
Trianthema portulacastrum		(1)				R
AMARANTHACEAE						
Achyranthes aspera	---	(1)			R	
ANACARDIACEAE						
Schinus terebinthefolius	Christmas berry	(1)			R	
ARECACEAE	(palms)					
Cocos nucifera	*niu*	(1)				R
ARALIACEAE						
Schefflera actinophylla	umbrella tree	(1)	R			
ASTERACEAE						
Pluchia carolinensis	sourbush	(1)			R	R
Pluchea indica	Indian sourbush	(2)		U		U
Pluchea X fosbergii	sourbush hybrid	(1)		R		
BATACEAE						
Batis maritima	*'ākulikuli kai*				**A**	**A**
BORAGINACEAE						
Heliotropium curassavicum	seaside heliotrope	(1)				U
CHENOPODIACEAE						
Atriplex semibaccata	Aust. saltbush	(1)		C		A
CYPERACEAE	(sedges)					
Cyperus involucratus	umbrella sedge					U
Schoenoplectus lascustris	bulrush		**A**			
FABACEAE						
Desmanthus pernambucanus	virgate mimosa	(1)	U			
Leucaena leucocephala	*koa haole*	(1)	O	C		
Macroptilium atropurpureum	---	(1)	R			
Prosopis pallida	*kiawe*	(1)		A	C	O
LAMIACEAE						
Leonotis nepetifolia	lion's ear	(1)		C		
MYRTACEAE						
Syzygium cumini	Java plum	(1)	U			

Table 3-03 (continued)

Species listed by family	Common name	Notes	Wetland ID No. ..3217 (a)	..4067	..4070	..4241 (b)
NYCTAGINACEAE						
Boerhavia coccinea	false *alena*	(1)				
POACEAE						
Cenchrus ciliaris	buffel grass	(1)		**A**	C	U
Chloris radiata	plushgrass	(1)		U	U	A
Cynodon dactylon	Bermuda grass	(1)				U
Pennisetum purpureum	elephant grass	(1)	A			
Sporobolis sp.	---	(1)		U	U	A
Urochloa maxima	Guinea grass	(1)	C	**A**		R
Urochloa mutica	Calif. grass		**A**			R
RHIZOPHORACEAE						
Rhizophora mangle	red mangrove		R			
VERBENACEAE						
Verbena littoralis	ōwī	(1)		R	R	
TYPHACEAE						
Typha latifolia	Cat tail		U			

Notes:

(a) Includes wetland ..3218

(b) Po'uhala marsh near energy corridor.

(1) Typically not a vegetation of wetland, but growing around margin.

(2) Marginal vegetation member; more typically growing close to wetland.

Table 3-04. Summary of Changes since 1999

Site	Description	Change since 1999	ACOE ID
West Loch north shore mangrove	Po'uhala Marsh.	On-going project to clean up marsh and playa areas and eliminate mangrove.	**..4241**
West Loch north shore mangrove	Kapakahi Stream estuary.	Mangroves removed from part of estuary.	**..4243**, **..4244**
West Loch northeast shore mangrove	Mostly a thin belt of mangrove off the old C&C ash landfill.	No change.	**..4245, ..4246, ..4517 (or ..4284)**

Table 3-04 (continued)

Former Oahu Sugar Co. settling ponds	Settling ponds that developed into extensive wetlands.	Use curtailed before 1999, and now completely dried up.	None
Scattered shoreline areas west of Walker Bay.	Small mangrove clusters.	Unchanged.	**..4062 through ..4066**
Walker Bay, north shore	Mangal with *Batis* flats behind.	Unchanged.	**..4068 through ..4072**
Inland of north side of Walker Bay	Playas in man-made catchment basins.	More than one feature is present.	**..4067**
Walker Bay, south shore	Narrow band of mangrove at shore.	Unchanged	**..4073 through ..4076**
Wetland west of degaussing sta.	Interior wetland	Not investigated.	**..4057**
West shore of Middle Loch	Narrow mangrove belt becoming mangal at north end.	Unchanged.	**..4052 through ..4056, ..4288**
Makalena Golf Course pond	Open water feature with margin of emergent vegetation.	Unchanged.	**..4060**
Kahu Drainage Channel	Mangroves lining modified drainage channels	Mangroves removed from smaller channels to maintain flood hydrology	..4076 to ..4078, **..4058, ..4059, ..4061**

Note: ID numbers in bold are jurisdictional wetlands; others are not.

Following are supplemental photographs (SP) for Chapter 3.

SP3-01 (left): Red mangrove growing on a concrete block and adjacent rocky cliff, a situation that fails to fit into a wetland definition.

SP3-02 (left): Another one of the playa-like depressions near Walker Bay (see Fig. 3-08). Here the only vegetation is *kiawe*. Note salt-encrusted soil, the only plausible explanation for which in the closed depress-sion is evaporation of saline groundwater.

SP3-03 (left): Hawaiian stilt (*Himantopus mexicanus knudseni*) on the shallow playa pond at Po'uhala Marsh.

Chapter 4

Middle Loch and Pearl City Peninsula

The wetland areas encompassed in this chapter correspond closely to ACOE (1999) Segments 5 and 6. Middle Loch is the central major subdivision of Pearl Harbor and the smallest loch (counting much smaller Northeast Loch as an arm of East Loch). Middle Loch is bounded by Waipi'o Peninsula (Chap. 3) on the west and Pearl City Peninsula on the east. Most of the Pearl City Peninsula is U.S. Navy land. However, extensive freshwater wetlands north (*mauka*) of the energy corridor (bike path), which cuts across the very top of the Peninsula, are outside of Navy jurisdiction (Fig. 4-01).

The upper part of the Pearl City Peninsula was mostly fishponds, *lo'i*, and marshlands. The lower end of the peninsula, developed as housing and other operational facilities of Pearl Harbor Naval Base, was at somewhat higher elevation and developed in the late 1800s (PHRI, 1994). The lowlands of the upper peninsula have been filled over time, and wetlands now are found where the land was not raised substantially by fill. Ditches were either dug out or low areas left in narrow strips between fill to facilitate local drainage. To reduce flood hazard, soil dikes isolate lower Waiawa Stream from the floodplain.

Middle Loch North Shore

The north shore of Middle Loch is accessed by an unimproved segment of the jogging/bike trail (energy corridor) and former OR&L right-of-way. The shoreline harbors a mostly thin and scattered border of red mangrove. The mangal is most extensively developed at the eastern end around the mouth of Waiawa Stream.

Kolea Cove Wetland ~ Just inland of the energy corridor near the middle of the north shore is a fenced wetland pond called Kolea Cove Wetland (ID ..6285; named presumably after a development planned for *mauka* properties) constructed as a mitigation (Okada Trucking, DA Permit 1594-S; ACOE, 1999).

Although this wetland is still present, access to view the wetland has become difficult by the fact that dense vegetation now obscures the fence, wetland margin, and most or all of the open water of the feature. The wetland is overgrown with California grass (*Urochloa mutica*) and cattail (*Typha latifolia*; Fig. 4-02). This feature is not indicated on the NWI maps (USFWS, 2007).

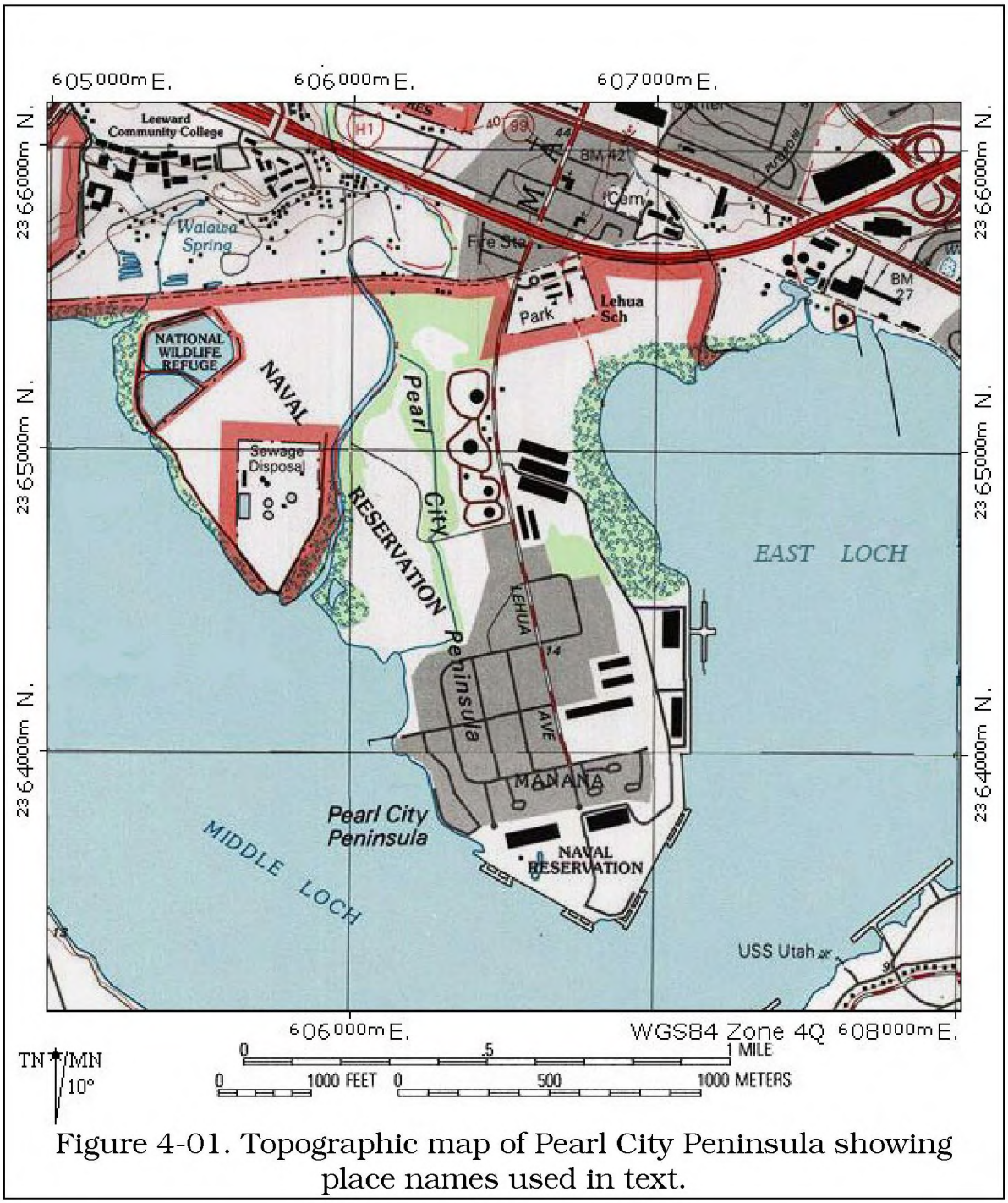


Figure 4-01. Topographic map of Pearl City Peninsula showing place names used in text.

Waiawa Springs and Bike Trail

Waiawa Springs are a series of springs lying along the base of the Ko'olau basalt bluffs below Leeward Community College. The elevation of the highest spring orifice is 3.4 m (11 ft) above sea level (Visher and Mink, 1964). Waiawa Springs

is actually the smallest of the major Pearl Harbor spring sites in discharge volume (average flow of 18 Mgd between 1911-1920 according to Nichols et al., 1997), but has the greatest remaining exposed surface area of the main Pearl Harbor springs with spring-fed ponds totaling 10.1 ha (25 a) in the early 1960's (Visher and Mink, 1964). However, Englund et al. (2000) reported that portions of the Waiawa Spring complex near the base of the basalt cliffs were possibly being filled and used as a heavy construction staging area.

Figure 4-02. Kolea Cove wetland as it appeared in September 2006 looking into the wetland from the northwest corner. Poles and trees in background are along the bike trail.

Numerous irrigation ditches occur at the Waiawa Springs complex, connecting ponds where watercress (*Nasturtium officinale*) is grown. Other areas consist of silty, vegetation covered ponds. Water can also be seen actively issuing from spring areas where the watercress farmers have cleared vegetation. Measured salinities at Waiawa Springs ranged from 3-5 ppt (Englund et al., 2000).

The watercress wetlands (ID ..6104 through ..6120, ..6122 through ..6125, ..6286 and several others not included in the ACOE inventory in 1999) include

several large parcels where watercress is actively farmed, numerous smaller basins that may have been used formerly for aquaculture (appear unsuitable for watercress) but are now abandoned (see photo SP4-02), and various drainage ditches.

Figure 4-03. Mangal [ID ..6079] denuded of mangrove trees fronting the Waiawa Unit, PHNWR (to left out of frame). Mangroves from which this photo was taken in September 2006 were later also removed.

One large wetland area that appears no longer to be used for watercress is wetland ID ..6125. We attempted to gain permission from the private owner to enter this property but were not successful. However, satellite images of this wetland show active filling underway, and the boundary interpreted from the images we used is considerably different (area reduced) from that indicated by the ACOE in 1999. Outflow from this wetland is into ID ..6124 (see photo SP4-01).

Overflowing water from the Waiawa Springs through the ponds and ditches, eventually discharges into Middle Loch at the northeast corner, adjacent to the Waiawa Unit of the Pearl Harbor National Wildlife Refuge (PHNWR). The mangal through which the outlet stream flowed and which extended southward in front of the PHNWR has been removed (2006-2007; Fig. 4-03, above).

Some water from the springs in this area floods westward beside the bike trail, creating small wetlands just off the trail and feeding man-made ponds in the area. On the south side of the trail, however, a shallow drainage ditch (ID ..6121) is covered in pickleweed (*Batis maritima*; Fig. 4-04), suggesting an infrequent but significant tidal connection, and disconnection from the abundant freshwater present elsewhere just north of the bike trail.

Figure 4-04. A small pickleweed wetland in the drainage ditch on the south side of the bikeway.

ACOE (1999, p. 38) noted the following in this area:

> Chevron ...was installing a new pipeline and excavated a trench near the bike path. The water surface was within 10 inches of the surface and the soil was very black, wet, and clearly hydric. Vegetation was primarily pickleweed with Indian fleabane. The strips with hydric vegetation next to the bicycle path in this area are considered wetlands. The ponds to the north next to the bike path were also field checked.

The ACOE (1999) identified some 22 wetland features (mostly active or former watercress ponds) north of the bike trail and west of Waiawa Stream (two in the upper oxbow bend of Waiawa Stream). We believe at least three more were

missed in 1999. The NWI (USFWS, 2007) shows 18 ponds in the same area (however, 6 of these are in the upper oxbow bend) and applies seven different codes, in addition to the outlet ditch coded as PEM1Cx (excavated palustrine wetland, seasonally flooded, persistent emergent vegetation). This channel feature is more correctly coded using one or all of the following: PUBHx, E1UBLx, or R2UBH.

Five of the NWI "pond" codes start with "PEM1" or palustrine persistent emergent vegetation, with these modifiers:

PEM1C — seasonally flooded
PEM1Fx — semipermanently flooded, excavated
PEM1Hx — permanently flooded, excavated
PEM1KFh – semipermanently and artificially flooded, diked/impounded
PEM1KFx - semipermanently and artificially flooded, excavated.

The other two codes applied are:

PUBHx — palustrine unconsolidated bottom, permanently flooded, excavated (an open pond or channel)
PSS1Kx — palustrine broad-leaved deciduous scrub-shrub, artificially flooded, excavated.

It is not clear what vegetation type is being described by PSS1Kx for a vegetated, artificial pond. The majority of the watercress ponds are coded PEM1KFx or Fh reflecting construction design. Although manipulation of flows might account for permanent vs. semipermanent vs. artificial flooding, these features are all fed by springs meaning "seasonally flooded" should not be used.

Waiawa Unit, PHNWR

The Waiawa Unit of the Pearl Harbor National Wildlife Refuge (PHNWR) is a 25-acre (10-ha) site on U.S. Navy land with two ponds (Fig. 4-05) supplied with fresh to slightly brackish water pumped from the nearby outlet of the Waiawa Springs complex (USFWS, 2006). As at the Honouliuli Unit of PHNWR (see Chapter 1), the site consists of two diked ponds (IDs ..6080 and ..6081). These drain via a short outlet located along the Middle Loch shore.

Biota sampling in the refuge ponds is reported by Englund et al. (2000). The ponds are surrounded by pickleweed and have mostly silty bottoms. Salinities were measured as follows (Englund et al., 2000, p. 25):

> Surface salinities were 1.9 ppt at the piped water outlet on the more inshore side of the refuge, while only 3.1 m (10 ft) away from the pipe outlet salinities increased to 5 ppt. Salinities averaged 9 ppt in the upper half of the diked area of the refuge and averaged 24 ppt in the diked portion of the refuge closest to the ocean.

Each pond is classified differently in the NWI (USFWS, 2007). The northern pond (ID..6080) is an open central pond, E1UBL (estuarine unconsolidated bottom subtidal) with margins E2EM1N: (estuarine persistent emergent herbaceous vegetation regularly flooded wetland). As pointed out elsewhere (see Introduction, p. 21), the correct code is E2SS3P. The southern pond (ID ..6081) is presently coded E1ABL (estuarine subtidal aquatic bed; i.e., submerged aquatic plants). Since both ponds are excavated features, in general similar to the ponds at the Honouliuli Unit (see page 46), the codings should be similar but are not.

Figure 4-05. Northernmost (ID ..6080) of the two ponds at the Waiawa Unit of the PHNWR, looking southwest. The dominant vegetation is pickleweed.

Waiawa Stream and Lower Floodplain

Waiawa Stream drains the west side of Pearl City, forming a double horseshoe bend as it flows out onto the coastal plain directly north of the center of the Pearl City Peninsula (Fig. 4-06). The stream continues to meander down the peninsula before flowing into Middle Loch nearly half way down the west side. The upper half of the peninsula is a floodplain that once supported extensive rice culture (PHRI, 1993). The mouth of the stream is a mangrove forest or mangal, and indicated on NWI maps as E2FO3N: estuarine, intertidal, regularly flooded, broad-leaved evergreen forest (USFWS, 2007) and shown extending upstream nearly to the point where Waipuna Avenue crosses the stream.

Figure 4-06. Satellite image of the lower end of Waiawa Stream and the abandoned WWTP to the west on the western side of the Pearl City Peninsula.

From the bridge at Waipuna Ave., the stream meanders southward then southwestward in a channel that is heavily overgrown with mangrove. Indeed, the mangrove forest or mangal lining the lower end of the estuary (ID ..6087 and ..6088) is impressive in its size and the height of the trees. Further, immediately southeast of the mouth is a large mangal with an open pond in the middle; the trees east of the pond form a curious circular patch 60 m (190 ft) in diameter. The whole looks very much like an ancient fishpond that is most of the way to being filled by mangrove. Yet, the 1897 land use map of the peninsula (in Helber, Hastert & Fee, 1994) shows no ancient fishpond in this area. From the historical map, it would appear that the open pond is simply an old outlet of Waiawa Stream.

Englund et al. (2000) suggests the upper tidal limit of Waiawa Stream as occurring near the USGS gage directly beneath the Kamehameha Highway bridge crossing. The water here was fresh. Salinities in the estuary downstream of this point ranged from 8 to 34 ppt; salinity at the old WWTP outfall in Middle Loch was 34 ppt.

Waiawa Wetlands ~ On the western or right bank of the stream, the land is high and apparently mostly fill, being once an area supporting extensive rice fields. To the east of the stream, the land is crossed by several berms[1], but a portion is low enough to remain as wetland. Wedged between the left bank of the Stream, Lehua Avenue, and a former Navy petroleum tank farm, this wetland was delineated by the ACOE in September 1992 for a feasibility study to construct sediment settling ponds (sediment removal facility or SRF) intended to reduce delivery of sediment loads into Pearl Harbor and enhance wetland wildlife habitat in the region (Helber Hastert & Fee, 1994). The feasibility study involved various natural and historical environmental surveys of interest (Char, 1993; Bruner, 1992, PHRI, 1993). ACOE (1999) remapped four wetlands in this area (ID ..6098, ..6099, ..6100, and ..6101) and concluded the wetlands had become reduced in area from what had been delineated previously. The dominant vegetation in three of the wetlands was California grass and umbrella sedge (*Cyperus involucratus*). However, one wetland (ID ..6098), was described as a "mixed forest wetland".

We were only able to access some parts of the wetlands in this area due to the density of the surrounding vegetation of mostly elephant grass (*Paspalum purpureum*). The ACOE (1999, p. 34) noted, for the westernmost wetland [ID ..6101) that "[e]lephant grass is encroaching into the area and is decreasing the jurisdictional area." We could not confirm that this wetland still exists. On the other hand, ID ..6098 is mostly a forest of Java plum (*Syzygium cumini*) and not a wetland, although towards the outlet feeding to a north-south drainage ditch (see below), *hau* (*Hibiscus tiliaceus*) and some mangrove (*Rhizophora mangle*) comprise a small swamp. The central area of the marsh remains dominated by umbrella sedge and California grass as described by ACOE (1999; see Fig. 4-07).

The NWI (USFWS, 2007) does not indicate any wetlands in this area. However, a large wetland coded PF03C (palustrine, broad-leaved evergreen forested,

[1] A north-south berm carries a pipe running from the City and County pump station to the abandoned Pearl City WWTP. An east-west second berm carries an 8-inch underground fuel line and runs from the energy corridor to the nearby, former Navy tank farm. Both berms are choked with heavy vegetation including elephant grass, monkeypod, and Java plum *(Syzygium cumini)*. Both berms also have low points which are breached during floods (ACOE, 1999).

seasonally flooded wetland) is indicated to the southwest from along Waiawa Stream to the drainage ditch (described below), and along the drainage ditch all the way to Waipuna Ave. This "wetland" is also shown as present along the right bank of the stream extending north nearly to the bikeway. Although a narrow wetland is present along the drainage ditch [ID ..6097], expanding somewhat just above Waipuna Ave. (see below), the PFO3C wetland shown in the NWI may not exist.

Figure 4-07. Waiawa wetlands seen in a satellite image (Microsoft, 2007). The dense, montypic growth of umbrella sedge is readily apparent, distinct from the surrounding California grass.

North-South Drainage Ditch ~ The southern wetland area described above (ID ..6098) drains out through a ditch directed nearly due south (ID ..6093 to ..6097 and ..6287; Fig. 4-06) along the west boundary of the former Navy tank farm. This ditch eventually turns westward behind naval housing units on Ashley Avenue. The numerical subdivisions of this wetland feature by ACOE (1999) represent segments between now abandoned concrete road bridges. The wetland is one continuous feature marked by a monotypic stand of red mangrove. A bridge crosses this ditch at Waipuna Ave., providing road access to the now abandoned C&C WWTP. Below the Waipuna Avenue bridge, standing water is evident all along the ditch, but mangroves form a closed canopy forest over the water. At one point the ditch wetland expands, forming a small

pickleweed wetland (ID ..6096) on the west side of the ditch. Immediately upstream of the Waipuna Ave. bridge, the ditch makes a realignment, and perhaps because of this or the presence of the bridge with choking mangrove growth upstream and downstream, the wetland expands in a crook to the west out onto to the road. This particular area is characterized by *'akulikuli* and Indian pluchea. A soil examination showed a mixture of red clay and limestone sand and rubble, without any gleying.

The ditch opens on a small inlet on the east side of Middle Loch some 350 m (1200 ft) southeast of the mouth of Waiawa Stream where a mangal (ID ..6091) covers the right (north) bank. A narrow strip of mangroves (ID ..6092) lines the shore south to the pier at the end of Lanakila Ave.

Wetland (ID ..6091; NWI E2FO3N) occurs south of, and disconnected from, the mangal at the mouth of Waiawa Stream. However, along the face of the landfill occurs a strip of pickleweed which was observed by the ACOE (1999) to flood at high tide and thus constitutes a wetland [ID ..6090].

The ditch itself, from a non-existent connection to Waiawa Stream to Waipuna Ave., is coded R4SBCx: an excavated, seasonally-flooded, intermittent stream bed channel. From the bridge southward, the ditch is E1UBLx: an excavated, unconsolidated bottom subtidal estuary (USFWS, 2007). It seems likely that the dividing line is well upstream of the bridge at whatever point mangrove growth is not supported.

Former Pearl City WWTP Site ~ A former C&C waste water treatment plant (WWTP), now abandoned, is located west of the mangal along lower Waiawa Stream and is surrounded by wetlands (see Fig. 4-06). The WWTP was built on fill land that is at a generally lower elevation than surrounding parcels, which are also fill. The site is thus separated from the surrounding land by various berms or dikes, including on the east, a dike that contains flood waters of Waiawa Stream. To the south and east are narrow wetlands (..6085 and ..6086) separate from both shoreline and stream mangals (that is, IDs ..6083 and ..6087).

The site drains towards a low area on the western edge (ID ..6084) that has become a pickleweed (*Batis*) dominated wetland with a playa feature at its upper (north) end (Fig. 4-08; also see Introduction, Fig. 3 and photo SP4-03). This wetland appears to drain towards a central point where there is a stand of mangrove (part of ID ..6083). Thus, a pond and pickleweed flat at the southern end (ID ..6085) does not appear to connect to either the adjacent Middle Loch or Waiawa Stream mouth, being separated from them by a berm or dike. The northern arm of the playa wetland is coded in the NWI as PEM1Rx (excavated

palustrine, persistent emergent herbaceous vegetation seasonally flooded wetland), which it is certainly not. E2SS3P is the correct coding. The other wetlands are not shown in the NWI (USFWS, 2007).

Figure 4-08. Pickleweed wetland on the west side of the old Pearl City WWTP. Biologists shown walking the wetland boundary with a GPS unit. Note that pickleweed grows up the bank, well beyond the wetland border.

Another similar wetland feature (ID ..6086; pickleweed flat with shallow ponds; see Introduction, Fig. 6), but one without any apparent inlet or outlet, is squeezed between the Waiawa Stream dike and a berm—perhaps representing the former sewer outfall route—that terminates at a concrete box structure at the shore. This wetland is utilized by Hawaiian stilt and contains shallow, flooded areas.

The former WWTP consists of roadways, buildings, and various concrete structures once utilized to treat sewage. The old sludge drying pits are interesting because the 10 rectangular concrete basins accumulate rainwater and support some growth of wetland plants (*Batis*) and are attractive to wetland birds (see photo SP4-04). On our visit on December 14, two pairs of stilt, a pair of sanderling, and at least one Pacific Golden plover were observed in the sludge basins. ACOE (1999, p. 36) relates a similar observation: "Some of the old tanks and basins [of the STP] collect water and were in use by stilts." These

basins are incorrectly coded PUBHx (USFWS, 2007), the same as a pond at the south end of the pickleweed wetland (which may be an artificial excavation).

Lower Pearl City Peninsula

There are no wetlands around the developed southern end of the Pearl City Peninsula (ACOE, 1999), although an occasional mangrove might be growing at the shore. South of the Middle Loch pier at the end of Lanakila Ave., the NWI (2007) shows a near shore coded E2EM1N (estuarine intertidal persistent emergent vegetation regularly flooded) at the shore, fronte by an E2ABM (estuarine intertidal aquatic bed irregularly exposed). This connects to or becomes a short mangrove shore (E2SS3N) at the south end. The feature is a reef remnant (or other antecedent platform) for which E2ABM (algal bed) seems correct within Pearl Harbor. The shore is a seawall with a small beach, so E2EM1N has no meaning.

West Shore, East Loch

Directly north of a Naval pier facility (Bldg. 992) on the eastern side of the peninsula occurs an extensive mangal [ID ..6102] running northward along the shore to the Navy property fence. On Navy property, the width of this forest reaches 140 m (450 ft). This mangal extends to and beyond the mouth of Waimanu Stream, where the mangrove extends inland up the channel some 160 m (540 ft; see Chap. 5).

This wetland is described in ACOE (1999, p. 31):

> The Navy property on this portion of the peninsula has been built up by at least 5 feet of fill. There is a large nonwetland area consisting primarily of construction debris and fill on the southern end of the forest. … [T]he forest of American mangrove rises 50-70 feet high and extends from the base of the [fill land] slope to the …shoreline. Remnant patches of sea purslane can be found landward of the forest. These are likely to be the areas of the former backshore areas prior to colonization by mangroves.
>
> Behind the warehouses …[now just concrete slabs], this wetland contained ponded water 4-10 inches deep and schools of mosquitofish *(Gambusia affinis)* were observed. Blackened leaves covered the bottom. A scorpion was observed in the ponded water area outside Building 72 (middle warehouse).

Navy property here extends to Wamanu Stream, although a large, private, plant nursery operation covers the parcel north of the Navy security fence between Lehua Avenue and the East Loch shore. A portion of the mangrove wetland (ID

..6103) bordering the plant nursery has been removed and the operation expanded across landfill in what was indicated as wetland by the ACOE in 1999 (ACOE, 1999).

The mangal at the East Loch shore is coded in the NWI (USFWS, 2007) as E2SS3N: estuarine intertidal broad-leaved scrub-shrub, regularly flooded wetland, although a more accurate coding would be E2FO3N. The new NWI maps show the portion lost to fill. The NWI maps (USFWS, 2007) show the estuary of Waimanu Stream as E1UBL (same as East Loch Pearl Harbor) extending up to the H-1 viaduct. Four large wetlands depicted inland and to the west on Navy land and coded PEM1KFh (USFWS, 1999) now have been removed from the inventory. However, an extensive area inland of the mangal on the east side of the stream is shown and coded E2EM1N: estuarine persistent emergent herbaceous vegetation, regularly flooded wetland (see Chap. 5).

Tables 4-01 and 4-02 summarize biological observations (fauna and flora, respectively) made in 2006-7 at various wetlands located in the upper Middle Loch and Pearl City Peninsula areas. Table 4-03 summarizes differences between what was reported for this area as present and surveyed in 1999 (ACOE, 1999) and our 2006-7 field observations.

Table 4-01. Aquatic biota listing for upper Middle Loch wetlands.

Species listed by family	Common name	Notes	Wetland ID No. 60801	61011	61113	61120	61121	61122	61124	61125	62885
	INVERTEBRATES										
MOLLUSCA, GASTROPODA											
THIARIDAE											
Melanoides tuberculata	Melanid snail					C					
ARTHROPODA, INSECTA											
ODONATA											
AESHNIDAE											
Anax junius	Green darner									U	
LIBELLULIDAE											
Crocothemis servillia	Scarlet skimmer			U			U	U	U		
Tramea lacerata	Black saddlebags					R					R
COENAGRIONIDAE											
Ischnura ramburii	Rambur's damselfly			U	R					U	

Table 4-01 (continued).

Species listed by family	Common name	Notes	Wetland ID No. .6080	.6081	.6113	.6120	.6121	.6124	.6125	.6285
	VERTEBRATES									
PISCES (fishes)										
CICHLIDAE										
Cichlasoma nigrotasciatum	Convict cichlid								O	
Oreochromis mssambicus	Mozambique tilapia					U				
Sarotherodon melanotheron	Black-chin tilapia							O	C	
GOBIIDAE										
Awaous guamensis	*ʻoʻopu nakea*			R						
POECILIIDAE										
Poecilia mexicana	Mexican molly			C				O	C	
AVES (birds)										
ARDEIDAE										
Bulbucus ibis	*Cattle egret*								R	
RECURVIROSTRIDAE										
Himantopus mexicanus knudseni	*Aeʻo*		U							
RALIIDAE										
Gallinula chloropus sandwicensis	*ʻAlae ʻula*								R	
SCOLOPACIDAE										
Arenaria interpres	*ʻAkekeke*		U							

KEY TO SYMBOLS USED IN TABLE: 4-01

Abundance categories:

R – Rare – only one or two individuals seen.
U – Uncommon – several to a dozen individuals observed.
O – Occasional – regularly encountered, but in small numbers.
C – Common - Seen everywhere, although generally not in large numbers.
A – Abundant – found in large numbers and widely distributed.
P – Present – noted as occurring, but quantitative information lacking.

Notes:

(a) Includes ..6080 and ..6081.
(b) Shallow, flooded area north side of bike path near ID ..6111.
(c) Outflow channel from springs and watercress ponds at bike trail.

Table 4-02. Flora listing for Middle Loch, Pearl City Peninsula, and other selected Chapter 4 wetland sites.

Species listed by family	Common name	Notes	Wetland ID No. .6120	.6121	.6122	.6124	.6125	.6285 (a)
ARECACEAE	(palms)							
Cocos nucifera	*niu*	(1)				U		
ASTERACEAE								
Pluchia carolinensis	sourbush	(1)	O			O		
Pluchea indica	Indian sourbush	(2)	C		O	U	U	
Pluchea X *fosbergii*	sourbush hybrid	(1)	O		U		U	
Sphagneticola trilobata	wedelia	(1)				O		
BATACEAE								
Batis maritima	*ʻākulikuli kai*			A				
CONVOLVULACEAE								
Ipomoea alba	moon flower	(1)			O			
CYPERACEAE	(sedges)							
Cyperus involucratus	umbrella sedge					A		
Cyperus polytstachyos	---					A		
Schoenoplectus sp.	bulrush		O					
FABACEAE								
Leucaena leucocephala	*koa haole*	(1)	U		O	U	A	
Macroptilium atropurpureum	---	(1)			U			
Prosopis pallid	*kiawe*	(1)	U		C		C	
GOODINACEAE								
Scaevola sericea	*naupaka*	(1)					A	
LEMNACEAE								
Lemna sp.	duckweed					U		
MORINGACEAE								
Moringa oleifera	horseradish tree	(1)				U		
MYRTACEAE								
Syzygium cumini	Java plum	(1)					U	
NYMPHAEACEAE								
Nymphaea sp.	water lily		A					
ONAGRACEAE								
Ludwigia octovalvis	*kamole*					R		
POACEAE								
Cenchrus ciliaris	buffel grass	(1)					A	
Cynodon dactylon	Bermuda grass	(1)				C		

Table 4-02 (continued).

Species listed by family	Common name	Notes	Wetland ID No. ..6120	..6121	..6124	..6125	..6285 (a)
POACEAE (cont.)							
Urochloa maxima	Guinea grass	(1)					U
Urochloa mutica	Calif. grass		A		A	C	A
PONTEDARIACEAE							
Eichhornia crassipes	water hyacinth					C	
SCROPHULARIACEAE							
Bacopa monnieri	*'ae'ae*		U			U	
TYPHACEAE							
Typha latifolia	cat tail		C		C	A	A

Notes:

(a) Kolea Cove wetland lies on the boundary and is included in this table, but is discussed in Chap. 3.
(1) Typically not a vegetation of wetland, but growing around margin.
(2) Marginal vegetation member; more typically growing close to wetland.

Table 4-03. Summary of Changes since 1999

Site	Description	Change since 1999	ACOE ID
Kolea Cove	Mitigation wetland	Much overgrown with loss of biological wetland functions.	**..6285**
Middle Loch, northwest shore wetlands	Shoreline mangal.	Significant portions of mangrove have been removed.	..6077, **..6079, ..6082**, and **..6083**
Waiawa Springs	Numerous ponds/diked enclosures used for watercress production.	Many have been abandoned or are overgrown; ..6125 reduced by fill.	**..6104 to ..6120 and ..6122 to ..6125**
Bikeway drainage ditch	Depression overgrown with *Batis*.	Unchanged.	**..6121**
Waiawa Unit, NWR	Man-made wildlife ponds.	Unchanged; although fronting mangrove removed (see ..6079).	**..6080. ..6081**
Waiawa wetlands	Remnant low areas on flood plain.	More overgrown with elephant grass.	**..6098 through ..6101**

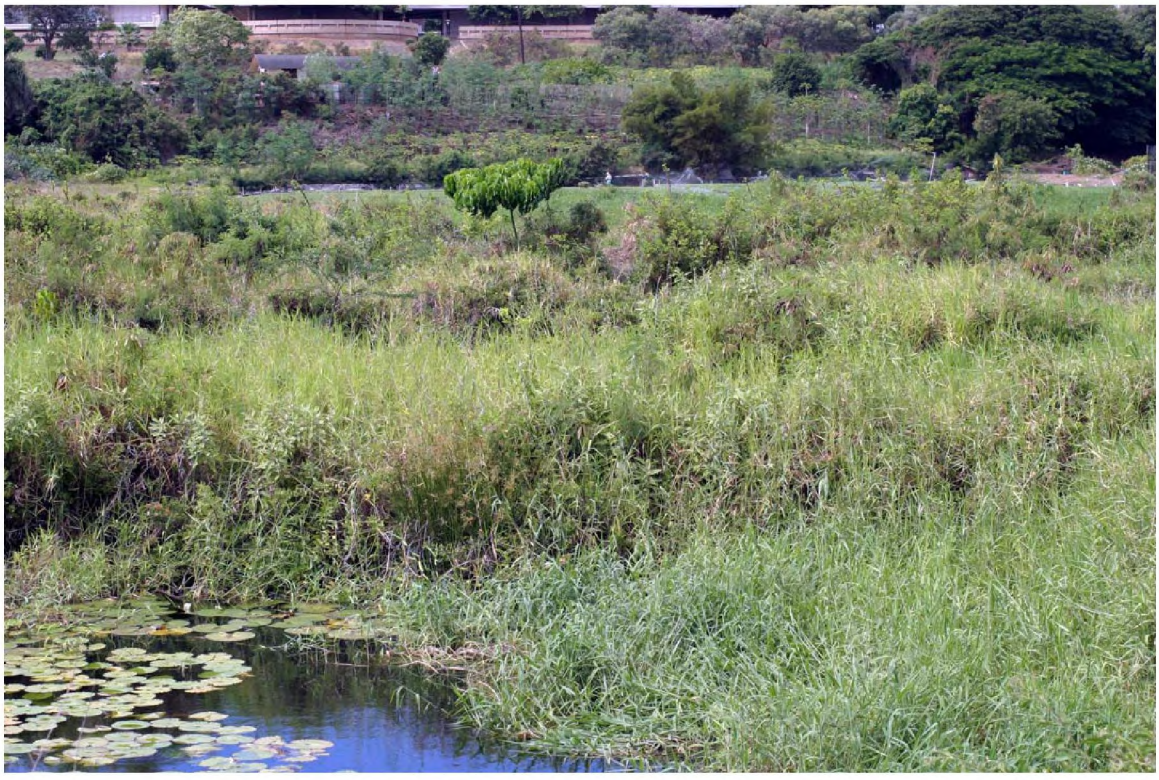
Table 4-03 (continued).

Site	Description	Change since 1999	ACOE ID
Former WWTP site	*Batis* wetlands and playa	Unchanged	**..6084 through ..6086**
Waiawa Stream estuary	Mangal.	Unchanged	**..6087, ..6088**
Drainage ditch	Narrow, mangrove-lined channel	Unchanged.	**..6098, ..6097, ..6093 through ..6096, ..6287**
Middle Loch east shore	Narrow shoreline mangrove bands,	Unchanged.	**..6090, ..6091, ..6092**
Northwest shore of East Loch	Shoreline mangal	Portion appears to have been filled.	**..6102, ..6103, ..7270**

Note: ID numbers in bold are jurisdictional wetlands; others are not.

Following are supplemental photographs (SP) for Chapter 4.

SP4-01 (above): One of the small pond wetlands (ID ..6124) fed by spring water in the Waiawa area showing how vegetation such as cattail and California grass can completely overgrow a freshwater wetland.



SP4-02 (above): Another pond (ID ..6120) in the same area as photo above. Because of a deeper basin and perhaps more recent use, the open water is not yet obliterated by California grass (growing out onto water surface from right).

SP4-03 (above): Salt encrusted soil at north end of the playa (ID ..6084) at the abandoned Pearl City WWTP.

SP4-04 (above): The abandoned sludge drying pits at the Pearl City WWTP are large concrete depressions that collect rainwater, support wetland plants (*Batis maritima*), and are visited by foraging Hawaiian stilt.

Chapter 5

North Shore of East Loch: Waiau to Kalauao Stream

The shoreline of most of the north shore of East Loch (Fig. 5-01) rises abruptly although only to about 6 ft (2 m) or so above sea level, the result of a long history of reclamation of tidal lands. However, in terms of physical requirements for wetlands, this area is comparable to the north shore of Middle Loch (Chap. 4) with numerous springs discharging inland from the shore, creating freshwater streams and wetlands. The entire area was once more extensively covered by wetlands that extended well inland of the harbor shore. Today, these wetlands are much reduced in area because highway and land development have encroached on the margins or completely filled them in, and outlet streams have been realigned and confined to narrow, man-made channels. Development in this area gradually shifted away from agriculture (rice in the early 20th century, later watercress) to commercial and industrial. A history of the lands around Waiau is reviewed in Coles (1979). The north shore of East Loch corresponds to ACOE (1999) Segment 7.

The Pearl City bikeway and state energy corridor (former OR&L right-of-way) is located closer to the shoreline of Pearl Harbor than any roads or highways and is adjacent to or traverses many of the wetlands in this area. There are no U.S. Navy wetlands in this segment

Pearl City Stream (aka Waimanu Stream)

Pearl City Stream at one time flowed between the wetlands associated with Kalua'o'opu Springs and Loko Kukono Springs to the HECO west end outlet weir (see below). In 1961, the stream was redirected into a new channel from the grounds of the former Hale Mohalu Hospital to an outlet along the shore 200 m (700 ft) further to the west (*AECOS*, 1994).

The stream flows in a lined channel from above Kamehameha Highway (State Rte. 99), under the H-1 Freeway and adjacent bikeway, and then into a soil bermed channel to Middle Loch. Vegetation in the streambed and on the banks include primrose willow, California grass, umbrella sedge, *'ape*, Guinea grass, castor bean, spiny amaranth, *koa haole*, scarlet-fruited gourd, Java plum, *kiawe*, and monkey pod. The only fish observed in the stream were tilapia (*Sarotherodon melanotheron*). Just *mauka* of the bikeway, the salinity in Pearl City Stream was 0 ppt (measured in the afternoon of 12/7/06).

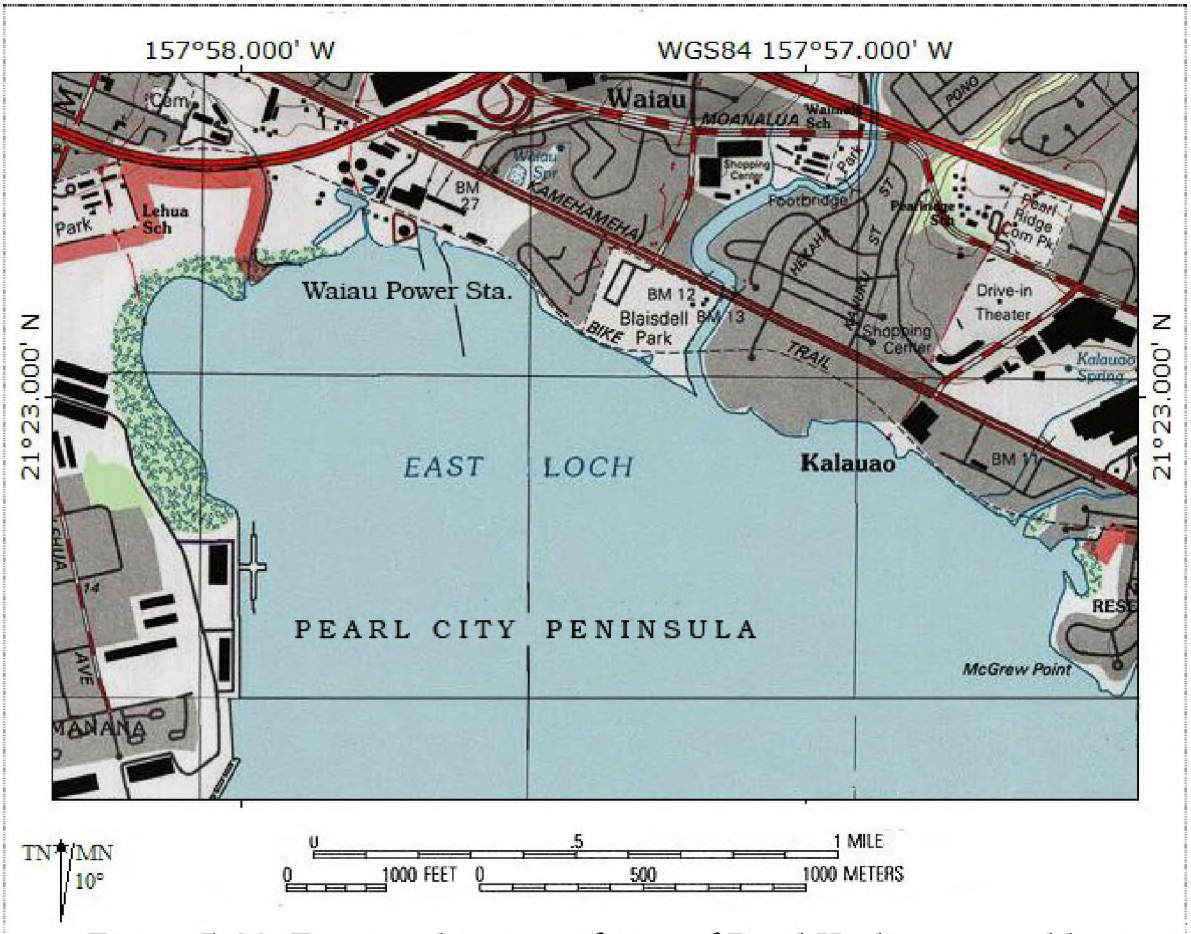


Figure 5-01. Topographic map of area of Pearl Harbor covered by Chapter 5 (the Pearl City Peninsula on left is covered in Chapter 4).

An extensive mangal (ID ..6103 and ..7270) is present along the shoreline west and east of the outlet of Pearl City Stream into East Loch. This growth extends southward to a Navy pier facility (Chap. 4). To the east, Hawaiian Electric (HECO) is removing mangroves fronting the Waiau Power Station.

The land north of the mangrove belt (ID ..6103) and west of Pearl City Stream is possibly Navy property and is bounded by a high security fence. ACOE (1999) indicated this as not Navy property and showed four wetlands present (ID ..6251 to ..6254), the arrangement and shapes of which suggest an abandoned agricultural (taro or watercress) complex. We were unable to locate this area because of access problems, including a dense growth of grasses.

The NWI maps (USFWS, 2007) show the estuary of Pearl City Stream as E1UBL (same as East Loch Pearl Harbor) and depict a very extensive area inland of the mangal on the east side of the stream coded E2EM1N: estuarine persistent emergent herbaceous vegetation, regularly flooded wetland. We are suspicious, based on aerial photographs, that a wetland indeed is present in this area,

although the ACOE inventory indicated nothing behind the coastal mangrove (ID ..7270; ACOE, 1999) and have roughly delineated the area (assigned ID .. 7269) which appears to connect eastward with the HECO West Outlet. Unfortunately, the property proved difficult to access because it is private and HECO Waiau Power Station bounds the east side. The mangal along the East Loch shore in this area extends nearly to the HECO discharge point and was correctly coded E2FO3N: estuarine intertidal, regularly flooded, broad-leaved evergreen forest (USFWS, 1999), but was changed recently to E2SS3N.

Figure 5-02. Satellite view of northwest corner of East Loch in the vicinity of the HECO Waiau Power Station showing features discussed in text.

Waiau Pond (Kalua'o'opu Spring and Waiau Marsh)

Waiau Pond is located on the grounds of the HECO Waiau Power Station and once served as the cooling water intake basin for the power plant. The pond was dredged out mostly in the 1940s. This basin was fed by numerous springs and associated wetlands (known as Kalua'o'opu, Loko Kukono, and Pu'ukapu) located behind the shoreline to the west of the plant, with the outflow from these springs directed eastward in a channel dug behind the East Loch shoreline. Water supply for cooling purposes was supplemented by artesian wells constructed in 1938 and excess water escaped over an outlet weir at the

shore. The cooling water discharge (from the plant) went to the channel that is now the east end outlet of the pond (Coles, 1979).

Waiau Pond is an open body of water surrounded on the north, east, and south by walls and bulkheads of the HECO facility. The wetland consists of an open water pond (see photo SP5-07), almost half of which supports tape grass (*Vallisneria spiralis*)—a submerged aquatic plant that is widely used in the aquarium trade and also eaten as a vegetable. During a survey in 2001 (*AECOS*, 2002), the vegetation of the wetland was found to be mostly cattail (*Typha* sp.) and California grass (*Brachiaria mutica*), but the ACOE (1999) found primarily tape grass. HECO regularly manages the pond by removing water hyacinth (*Eichhornia crassipes*) and other vegetation.

The clarity of the water was excellent at the time of our visit, although the bottom is mostly a fine silt deposit that clouds the water if disturbed. The pond depth is over 3 ft (1 m). Tilapia (*Sarotherdon* sp. and mollies (*Poecilia mexicana*) are abundant at least along the edges of the pond. Flume clams and crayfish burrow in the bottom of the pond. During December 2006, several different types of water birds were seen foraging and resting in the pond, including the endangered Hawaiian stilt (*Himantopus mexicanus knudseni*) and indigenous *'auku'u* (*Nictycorax nictycorax hoactli*). David (2001) reports results of avian surveys in the pond and includes a single sighting of a Hawaiian duck/mallard hybrid (*Anas wyvilliana* x *platyrhynchos*). Coles (1979) reported observing a Hawaiian coot (*Fulica americana alai*) in a part of the wetland that no longer exists. The salinity in the Waiau Ponds was 0 ppt throughout, as measured in several places on the afternoon of 12/6/06.

Waiau Pond as it presently appears is clearly not a wetland; the delineation manual (ACOE, 1987, p. 14) defines as "vegetated shallows" of "deepwater aquatic habitat" areas less than 6.6 ft (2 m) deep that support only submerged aquatic plants. Boundaries of the pond include bulkheads of concrete and a wall of vertical wood piles, in addition to shoreline areas that appear to have been dredged in soil or fill. Weir gates and boards enable HECO to manipulate water level in Waiau Pond, allowing for management options in terms of controlling invasive plants and regulating water depth. This maintenance does present a problem in defining the wetland status in as much as the ACOE manual includes in the definition of wetlands the phrase "under normal circumstances" to cover situations where removal or alteration of emergent vegetation impacts on the delineation mechanism. The absence of emergent vegetation in some parts of the pond would seem to be largely the result of human activities, and ACOE (1999) delineated the western half as ID ..7268.

Wetlands west of the HECO Generating Station end in the *mauka* direction more or less abruptly at the H-1 viaduct. Although the Interstate is supported on piles high above the ground in this section, any wetland features that were present within the r-o-w of the freeway were apparently filled in. The swath cut by the freeway through former wetlands here is evident in Fig. 5-02. Waimano Drainage Channel crosses under the viaduct in an open culvert, and a pipe culvert to the east drains a wetland (ID ..6255) on the north side of the freeway. This particular wetland was surveyed by Guinther (2003) and found to be fed by several springs. The wetland status of the westernmost portion is not firmly established (due to the nature of the soil), but the area was an abandoned pond field overgrown with dayflower (*Commelina diffusa*) and fed by a capped and valved freshwater spring located close to the man-made channel of Waimano Drainage Channel. The springs in this area feed pondfields (Fig. 5-03; also SP5-02) along the bike path west of the HECO Generating Station (ID ..7257 through ..7267).

Figure 5-03. Taro, ung choi, and watercress pondfields or *lo'i* (ID .. 7259 and ..7260 in foreground) utilizing spring water flowing towards East Loch on the west side of the HECO Waiau Generating Station (background). The public bike path can be seen on the left.

These ponds are indicated in the NWI (USFWS, 2007) and coded PEM1KFh: palustrine persistent emergent herbaceous vegetation, semipermanently and artificially flooded, diked impoundments (i.e, pondfields).

Waiau Spring and Wetland

Waiau Spring arises some 1300 ft (410 m) inland of the shore and its perennial discharge, Waiau Stream, flows through small watercress (*Nasturtium microphyllum*) and taro plots and then a pond and wetland (ID ..7128) before entering a concrete culvert under Kamehameha Highway (State Rte. 99) and then a narrow channel on the east side of HECO's Waiau Power Station. This remnant wetland (see photo SP5-01) can be observed from the Zippy's parking lot off Kamehameha Highway or from an access road at the intersection of Kuleana Road and Kuleana Place. A concrete culvert curves around the east side of the wetland and directs drainage from the H-1 Interstate/Moanalua Road interchange past Zippy's to a culvert under Kamehameha Highway. The wetland appears to be mostly overgrown with California grass, water hyacinth, and umbrella sedge, with small pond field areas of ung choi and taro. Open water (primarily at the south end) supports the tape grass (*Vallisneria*), a submerged aquatic plant, which we observed being harvested.

The drainage channel below Kamehameha Highway is unlined and has a natural rock bottom, but it is clearly shaped by man-made landscape features. It seems likely that this is not the original bed of Waiau Stream, although it has probably served as the drainage outlet for Waiau Spring since the HECO Generating Station was constructed in the 1930s. It is possible that outflow from Waiau Spring originally fed into the complex of ponds and wetlands to the west of the power plant (*AECOS*, 2002). Waiau Stream flows through a culvert under the Pearl City bikeway and into a mangrove belt (ID ..7131) along the northern shore of East Loch.

Makai of the bikeway, the east side of the channel is lined with mangrove and also has Indian fleabane and *koa haole* growing on the upper banks. The stream harbors mostly tilapia (*Sarotherodon melanotheron*), flume clam, and the endemic *aholehole* (*Kuhlia xenura*), which was common. Just *makai* of the bikeway, the salinity in Waiau Stream was 0 ppt and off the East Loch shoreline west of the stream mouth the salinity was 5 ppt (measured at 9 am on 12/1/06).

Mangroves once present along the shore to the west of the mouth have been removed (see photo SP5-03). Scattered colonization by red mangrove occur all along the shore between the Waiau Generating Station and Neal S. Blaisdell Park. Those clusters (ID ..7129 & ..7130) directly fronting the east end of the

HECO facility were removed and the land along the bike path to the shore made into a well-maintained wayside park. A mangal (ID ..7131 in part) is present east of the drainage from Waiau Spring and (ID ..7132) along the shore opposite the eastern end of Kaluamoi Drive. All of the others (ID .. 7133, ..7271 through ..7174) fronting and west from Blaisdell Park have been removed. Effort is underway to clear ID ..7132.

The wetland around Waiau Spring is indicated by the NWI (USFWS, 2007) as consisting of two parts coded E1UBL (estuarine subtidal unconsolidated bottom) and E2USN (estuarine intertidal regularly flooded unconsolidated shore). Although possibly a close call given that the vegetation (formerly cattail) is regularly removed from the unconsolidated shore, the pond is fed by springs that flow year-round, so this feature is more likely to fall under the definition of a palustrine environment as it was previously identified (USFWS, 1999).

No wetlands are indicated to the east of the HECO facility on the NWI map (USFWS, 2007) other than small mangrove clusters (ID ..7131 and ..7132) shown as E2SS3N: estuarine, intertidal regularly flooded, broad-leaved evergreen scrub-shrub.

Waimalu Stream and Estuary

Waimalu Stream is tidal at least up to the H-1 Interstate and concrete lined from Kamehameha Highway to well upslope of the Interstate. Englund et al. (2000) suggest tidal influence extends to the USGS gage at the upper end of the concrete-lined channel, and reported fresh water by the H-1 viaduct, and salinities ranging from 32 to 37 near the stream mouth. The estuary is unlined (although channelized) below Kamehameha Hwy. and the banks support red mangrove from the highway bridge down to the bike trail bridge (ID ..7134 through ..7139), a distance of approximately 450 ft (140 m), and a large stand of mangrove (ID ..7145) on the west (right) bank extending another 450 ft to the mouth of the stream at East Loch. A narrow band of mangrove lines most of the left bank as well (ID ..7146 to ..7151). Wetlands misidentified by ACOE (1999) as ID ..7135 and ..7137 are large kiawe trees along the right bank of the estuary.

The west side of the delta of Waimalu Stream is a wetland (Fig. 5-04; ID ..7140) covered by a monotypic stand of pickleweed, with the large stand of mangrove on Wamalu estuary (ID ..7145; east side) and along much of the harbor side (ID ..7142 to ..7144). The inland boundary of this wetland is defined by the bike trail as it passes through Neal S. Blaisdell Park in Pearl City.

This area (especially the adjacent mangal) is utilized by homeless persons that have set up camps in and adjacent to the Park. In the wetland, rock-walled planters have been constructed to grow ornamental and food plants. Two such planters are visible in Fig. 5-04: one on the far left with a small palm tree, and one on the right close to the mangroves, where ti plants and squash or cucumber plants are being tended (see also photo SP5-04).

Fig. 5-04. Wetland (ID ..7140) at Neal S. Blaisdell Park in Pearl City. The estuary of Waimalu Stream lies beyond the mangal (ID ..7145) in the back; East Loch is beyond mangal (ID ..7142) on right.

The NWI maps (USFWS, 2007) indicate only that the estuary of Waimalu Stream is E1UBL: estuarine subtidal unconsolidated bottom; and there are areas of mangrove along the estuary and at the mouth coded E2SS3N. The larger mangals should be E2FO3N: estuarine, intertidal regularly flooded, broad-leaved evergreen forest.

Drainage ditch at Harbor Center

Harbor Center is located at the end of Hekaha Street. This area drains through underground culverts that appear to empty into a small inlet at the shore of

East Loch some 220 ft (70 m) east of Waimalu Stream mouth. A portion of this drainage system includes open ditches on either side of Hekaha Street along the south side of the bike path. These ditches are apparently tidal, and support small wetlands (ID ..7152), dominated in one case by seashore paspalum (*Paspalum virginicum*) with a sparse growth of pickleweed, and pickleweed, mangrove, and Indian fleabane in the other case (Fig. 5-05).

Figure 5-05. Drainage ditch along bike path adjacent to Harbor Center (left) in Pearl City (Hekaha St. at stop sign).

A drainage ditch drains Kamehameha Highway in front of Cutter Ford (98-015 Kamehameha Hwy, Aiea, HI), flowing into Waimalu estuary. This ditch supported only Indian fleabane at the time it was inspected (10/25/06); grass in the ditch appeared to have been killed by standing water. This ditch is likely to be dry much of the time, and, unlike the ditch along the bike path, is not reached by the tide and would not be jurisdictional.

The tidal drainage ditches on the *mauka* side of Harbor Center are connected by underground culvert to an outlet along the shore opening into a small inlet just east of the mouth of Waimalu estuary. Another long drainage ditch (ID ..7275) is present along the east boundary of Harbor court.

Kalauao

The shoreline of East Loch between the outlets of Waimalu and Kalauao streams is partly hardened with walls and massive boulders and partly eroded, with narrow, sand and/or rubble beaches. Red mangrove appears mostly as scattered shrubs taking hold on boulder and sand shorelines (ID ..7047, ..7048, and ..7153 through ..7159, and ..9040; see photos SP5-05 and SP5-06). One grouping has formed a mangal wetland (ID ..7158 and ..7159) marginal to an old iron pier and an unnamed drainage outlet east of an auto wrecking yard. The others are jurisdictional by virtue of being tidal, but are small patches on boulder substrata. Extensive mangal along the shore is present off the outlets from Kalauao Spring and nearby Kalauao Stream.

Figure 5-06. Sumida Farm: watercress farming in pond fields. Only the downstream or *makai* end of an extensive growing area is shown here.

Kalauao Spring and Sumida Farm ~ Kalauao Spring is one of the many large springs that issue from the bedrock inland of the shore of East Loch. In this case, the spring issues forth *mauka* of Kamehameha Highway (State Rte. 99) in a low area surrounded by the Pearl Ridge Shopping Center and the water is utilized to support extensive wetland watercress farming at Sumida Farms

(Fig. 5-06, above). In 1964, the maximum width of the spring area was 244 m (800 ft), extending to the south side of Kamehameha Highway (Visher and Mink, 1964).

Outflow from the pond fields is directed into a concrete-lined culvert that also receives intermittent flow from a stream draining the Pearl Country Club. The stream feeds into a small estuary west of the mouth of Kalauao Stream. Salinities in the estuary and in the watercress area were measured at 2-3 ppt by Englund et al. (2000).

Pearl Kai Mitigation Wetland ~ ACOE (1999) relates the following concerning this area:

> Department of the Army permit number PODCO 1987 was issued to the developer of the Pearl Kai Shopping Center for the placement of fill in the wetlands. To account for the flood storage wetland function, the shopping center's building closest to [Kalauao Stream] was built on posts. As additional mitigation for placing fill in the wetland, mangroves were removed and a wetland pond and nesting island were constructed (Figure 35). Wetland vegetation at the site area includes *Cyperus difformis, Paspalum conjugatum, Cyperus polystachyos,* water hyssop, California grass, umbrella sedge, and mangrove....

Unfortunately, although the wetland was located along the bikeway, it no longer resembles the photograph provided by ACOE (1999, Fig. 35). It is our belief that a much overgrown wetland wedged between the bike path and the south side of the unnamed estuary (ID ..7038) is this mitigation wetland. A small area of shaded open water is visible from the bikeway side of the fence, but most of the wetland is obscured by California grass.

The pond fields of Sumida Farm are correctly coded (USFWS, 2007) PEM1KHh: palustrine emergent persistent herbaceous vegetation, permanently and artificially flooded, diked impoundment. The mitigation wetland is coded E2EM1N: estuarine intertidal persistent emergent herbaceous vegetation regularly flooded wetland. This feature is more likely a palustrine wetland environment given the vegetation present and an artificially dredged or diked one.

Kalauao Stream ~ Kalauao is a long stream that drains the Ko'olau from the ridgeline, flowing to East Loch along the western margin of 'Aiea. The stream is tidal most of the way upstream to the Kamehameha Highway viaduct. Buildings adjacent to this estuarine segment are separated from the stream by low retaining walls, but the stream probably experiences significant flooding as

some of these buildings are built on pilings. Englund et al. (2000) mentions that one building on pilings adjacent to the stream "was unfortunately built directly over [a] large spring."

Mangrove dominates the left bank and *milo* trees and Indian fleabane bushes are scattered throughout the area. However, the right bank has been cleared of all trees from the mouth to Kamehameha Highway. Only a small patch of pickleweed and mangrove seedlings are growing on shoaled areas along this side of the estuary. Tilapia are abundant. Just *mauka* of the bikeway, the salinity in the estuary was 20 ppt (measured in the afternoon of 12/7/06). Englund et al. (2000) recorded salinities ranging from 7 to 12 ppt in the stream channel, and 7 to 9 ppt at the spring outlet on the surface and 27 ppt at 0.3 m (1 ft) depth.

The only coastal wetlands shown by USFWS (1999) in the NWI east of Waimalu Stream are mangroves at the mouth of Kalauao Stream, indicated as E2SS3N: estuarine, intertidal regularly flooded, broad-leaved evergreen scrub-shrub. More applicable to mature mangrove stands would be E2FO3N.

Not far beyond the mouth of Kalauao Stream is McGrew Point, a Naval housing area covered in Chap. 6.

Tables 5-01 and 5-02 summarize biological observations (fauna and flora, respectively) made in 2006 at various wetlands located in the upper East Loch a area. Table 5-03 summarizes differences between what was reported for this area as present and surveyed in 1999 (ACOE, 1999) and our 2006-7 field observations.

Table 5-01. Checklist of aquatic biota observed in upper East Loch wetlands.

			Wetland ID No.				
			.7036	.7128 (a)	.7145 (b)	.7049	.7275
Species listed by family	Common name	Notes					
INVERTEBRATES							
MOLLUSCA, GASTROPODA							
THIARIDAE							
Melanoides tuberculata	Melanid snail			A			
MOLLUSCA, BIVALVIA							
CORBICULIDAE							
Corbicula fluminea	Flume clam			A			
OSTREIDAE							
Crassostrea virginica	American oyster		A				U

Table 5-01 (continued).

Species listed by family	Common name	Notes	Wetland ID No. .7036	.7128	.7145 (a)	.7049 (b)	.7275
ARTHROPODA, CRUSTACEA							
CAMBARIDAE							
Procambarus clarki	American crayfish			C			
GRAPSIDAE							
Grapsus tenuicrustatus	Rock grab		C				C
PORTUNIDAE							
Scylla serrata	Samoan crab				O		
VERTEBRATES							
VERTEBRATA, PICES							
CICHLIDAE							
Sarotherodon melanotheron	Black-Chin Tilapia		A	A	A	C	
KUHLIIDAE							
Kuhlia xenura	*Aholehole*			C			
MUGLIDAE							
Mugil cf. *cephalus*	mullet				C		
POECILIIDAE							
Poecilia mexicana	Mexican Molly		C			C	
VERTEBRATA, AMPHIBIA							
RANIDAE							
Rana catesbeiana	Bullfrog			O			
Rana catesbeiana	Bullfrog (tadpoles)			C			
VERTEBRATA, AVES							
ARDEIDAE							
Nycticorax nyticorax hoactli	*'Auku'u*		R				

KEY TO SYMBOLS USED IN TABLE 5-01:

Status:

Nat – naturalized – A n introduced or exotic species.

Ind – indigenous – A native species also found elsewhere in the Pacific.

Abundance categories:

R – Rare – only one or two individuals seen.

U – Uncommon – several to a dozen individuals observed.

O – Occasional – regularly encountered, but in small numbers.

C – Common – Seen everywhere, although generally not in large numbers.

A – Abundant – found in large numbers and widely distributed.

P – Present – noted as occurring, but quantitative information lacking.

NOTES:

(a) Includes stream down to bike path.

(b) Includes other mangrove areas along Waimalu estuary.

Table 5-02. Flora listing for Upper East Loch wetlands.

Species listed by family	Common name	Notes	Wetland ID No. .703737	.704232	.711332	.711440	.711552	.712755
ACANTHACEAE	(palms)							
Asystasia gangetica	*Chinese violet*	(1)			U			
ASTERACEAE								
Bidens pilosa	beggartick	(1)				U		
Pluchia carolinensis	sourbush	(1)		O				
Pluchea indica	Indian sourbush	(2)		O	C	O	O	C
Sphagneticola trilobata	wedelia	(1)		C				
Tridax procumbens	coat buttons	(1)				U		
BATACEAE								
Batis maritima	*ʻākulikuli kai*		A			A	A	A
CYPERACEAE	(sedges)							
Cyperus involucratus	umbrella sedge			C	O			
FABACEAE								
Desmanthus purnambucanus	virgate mimosa	(1)			U			
Leucaena leucocephala	*koa haole*	(1)		C				R
Pithecellobium dulce	*ʻopiuma*	(1)		U				
Senna surattensis	*kolomana*			R				
MALVACEAE								
Sida ciliaris	---	(1)				U		
Sida rhombifolia	---	(1)				U		
Thespesia populnea	milo	(1)			C	O		
NYCTAGINACEAE								
Boerhavia coccinea	false alena	(1)				R		
POACEAE								
Bothriochloa pertusa	pitted beardgrass	(1)				O		
Cenchrus echinatus	sandbur	(1)				U		
Chloris sp.	finger grass	(1)				O		
Paspalum virginicum		(1)					C	C
Sporobolus sp.	---	(1)				O		
Urochloa mutica	Calif. grass			A				
POLYGONACEAE								
Coccoloba uvifera	sea grape							R
RHIZOPHACEAE								
Rhizophora mangle	red mangrove			O	(a)	O	O	O

Table 5-02 (continued).

Notes:
(a) Mangroves recently removed.
(1) Typically not a vegetation of wetland, but growing around margin.
(2) Marginal vegetation member; more typically growing close to wetland.

Table 5-03. Summary of Changes since 1999

Site	Description	Change since 1999	ACOE ID
Northwest shore of East Loch	Shoreline mangal	Portion appears to have been filled since 1999.	**..6103**
North shore of East Loch	Shoreline mangal	Mangroves removed in front of HECO Waiau Plant.	**..7270**
Abandoned pondfields	Four diked ponds presumably used for watercress or taro production.	Abandoned before 1999.	**..6251 to ..6254**
Pondfields north of H-1	Spring-fed, diked ponds used for watercress or taro production.	Still in use.	**..6255**
Pondfields south of H-1	Spring-fed, diked ponds used for watercress or taro production.	Most still in agricultural use.	**..7256** through **..7267**
Waiau cooling water pond.	Spring-fed, diked pond(s).	Emergent vegetation lacking.	..7268
East of Pearl City Stream.	Palustrine wet area(s).	Only ..7258 seen in 1999.	**..7258, ..7269**
Shoreline mangrove east from Waiau to Blasdell Park.	Isolated mangrove copses and mangal.	Most or all of the mangrove has been removed	..7129, ..7130, **..7131**, ..7132, ..7133, and ..7271-76
Waiau wetland north of Kamehameha Hwy.	Spring-fed wetland with pondfields.	Small agricultural plots.	**..7128**
Blaisdell Park	Mangrove and pickleweed flat.	Mangrove growth consolidated into mangal.	**..7140, ..7144, ..7145**
Kalauao Spring	Sumida Watercress Farm,	Commercial use continues.	**.7049**
Harbor Center	Drainage ditches.	No change.	**..7152, ..7275**

Table 5-03 (continued).

Site	Description	Change since 1999	ACOE ID
Mangroves, Waimalu Stream to Kalauao Stream	Isolated mangrove copses and some mangal areas.	Some consolidation, other growths are too small to regard as wetlands.	**.7035-8,** ..7040, **..7041, 7043,**.7047-8, ..7053-6, **..7057-9,** ..7283
Pearl Kai wetland	Mitigation wetland.	Generally overgrown.	**..7042**

Note: ID numbers in bold are jurisdictional wetlands; others are not.

Following are supplemental photographs (SP) for Chapter 5.

SP5-01 (above): The small wetland (ID ..7128) fed by Waiau Spring is adjacent to Zippy's on Kamehameha Highway and supports local wetland gardening.

SP5-02 (left): Outlet of the pipe that caries water from springs located north of the H-1 freeway to pondfields (ID ..7266) directly west of HECO Waiau Power Station. Watercress and taro shown.

SP5-03 (left): Mangrove removal in progress along the shoreline west of Blaisdell Park.

SP5-04 (left): View from the shorerline into wetland at Blaisdell Park (ID ..7140) showing "garden" constructed of boulders in order to raise soil above the tidal influence.

SP5-05 (left): Shoreline near drainage channel (ID ..7275) is a massive boulder revetment protecting commercial property behind. Note that pickle-weed, milo, and red mangrove have colonized the supratidal.

SP5-06 (left): Mangroves becoming well established on the rock revetment near the photo in SP5-05 (ID ..7153) do not constitute a wetland.

SP5-07 (left): Connecting channel between ponds at the HECO Waiau Power Station. Note long leaves of tape grass (*Vallisneria spiralis*), a submerged aquatic plant.

Chapter 6

Eastern Shore: McGrew Point to Bishop Point and Ford Island

The shoreline along the east side of Pearl Harbor is mostly developed in various piers and docks or otherwise rises abruptly from the water, the result of a long history of development and reclamation on tidal lands. Coastal property and nearshore waters in this area are entirely under control of the U.S. Navy with a few exceptions. Along with Mānana on the Pearl City Peninsula (Chap. 5) and Ford Island (see below), this part of greater Pearl Harbor is the heart of U.S. Naval Base Pearl Harbor. The east shore of East Loch corresponds to ACOE (1999) Segments 8, 9, 10, and 11. Ford Island was designated Segment 12 in the ACOE report.

Along the East Loch shore beyond Kalauao Stream mouth is a housing area on ʻAiea Kai Way consisting of several lots on fill land behind a sea wall (PODCO 1401-S) and, just beyond, the peninsula known as McGrew Point. The remnants of Loko Paʻaiau, an ancient fishpond, lie at the shore off the western side of this peninsula. The fishpond is U.S. Navy property, part of McGrew Point Navy Housing. This area *makai* of the bike path is low-lying, with mangrove trees growing right up to the back of several of the houses.

The drainage ditch along the *mauka* side of the bikeway and a pond in the backyard of a house close to Kalauao Stream (the pond connected to the stream) are coded by USFWS (2007) E1UBLx: estuarine subtidal unconsolidated bottom subtidal excavated (that is, man-made, excavated below tide level).

Loko Paʻaiau

Loko Paʻaiau is mostly overgrown with red mangrove and generally inaccessible, although a central, open water area remains, connected to an opening into East Loch at the pond's north end. The pond biota is described as follows (ACOE, 1999, p. 46):

> There were no waterbirds observed during several visits to the fishpond. Patches of monotypic stands of pickleweed occur along the shoreline and at the opening of the fishpond. However, American mangrove is the predominant vegetation in and around Loko Paaiau. Towards the edges *hau*, Guinea grass, Indian fleabane, *koa haole, kiawe*, and *ʻopiuma* (*Pithecellobium dulce*) are common.

Loko Pa'aiau, or at least the vegetated portion, is coded E2SS3N: estuarine, intertidal, broad-leaved evergreen scrub-shrub, regularly flooded wetland on NWI (USFWS, 2007) maps. We would argue that a more appropriate classification for mangal would be E2FO3N: estuarine, intertidal, broad-leaved evergreen forested, regularly flooded wetland (i.e., mangal).

McGrew Point Housing

Navy property known as McGrew Point Housing lies *makai* (south) of the bike path between private property along 'Aiea Kai Way and state land at 'Aiea Bay Recreation Area. East of Pa'aiau and just off the bike path was a soccer field within the McGrew Point Housing area. This field was part of recreational facilities located on low-lying ground that bounded the fishpond on the east and south. This area has been undergoing enhancement and redevelopment and the former soccer field is presently being used as a storage/staging area for the contractors. One or two drainage ditches can still be located in the area as described by ACOE (1999):

> There is a drainage ditch that exits seaward of the soccer field and adjacent to a portion of the fence. This area contains water hyssop and there is an open water connection. This area is fenced and also considered a wetland. The field is low in this vicinity and the ground was saturated at the time of visit. If the field was not maintained, it is likely that this area could revert to a wetland.

Although it is unclear how maintenance prevents the soccer field from reverting to a wetland, the boundary fence along the western edge of the field does appear to cross through wetlands fed by the drainage features and having standing water in channels inland from the former fishpond. Ongoing disturbance resulting from activities related to housing construction made establishing a wetland boundary here not possible with any certainty, but development in this area under Navy control is close to the boundary.

ACOE (1999, p. 48) also describes another area somewhere nearby at McGrew Point:

> At the shoreline on the housing side of the fence is a low lying area that is covered with pickleweed. This area was mowed between the two visits and the area is likely to be maintained. Based on the hydrology and a soil sample taken at this site, the area is a wetland.

Apparently this location was not designated (assigned a code number and mapped) or delineated by ACOE. All that could be located in 2007 was a small

beach covered by pickleweed in an area near the tennis courts and used for a time as a parking lot for construction workers.

The southern and eastern sides of McGrew Point drop steeply to the shoreline in most places. Scattered small pockets of red mangrove have become established all along this shore. None of these mostly isolated mangroves is particularly well developed as mangal and therefore not regarded as a wetland, but rather as mangrove plants clinging to the jurisdictional tidal shore. However, the largest (ID ..8007) is perhaps approaching a mangal in structure. Mangrove growth on the boundary between Navy property and state property (‘Aiea Bay State Recreation Area) in the northwest corner of ‘Aiea Bay was assigned four separate codes by ACOE (1999; ID 9024, ..9025, ..9026, & ..9027), although none appears to represent an actual wetland. Without intervention, these mangroves may expand and coalesce, becoming a mangal wetland.

The wetlands shown around McGrew Point on the NWI map (USFWS, 2007) are Loko Pa‘aiau as noted above and a narrow belt along the entire southeast shore and in a man-made cove-like feature off the southern tip, both areas coded E2SS3N: estuarine, intertidal, broad-leaved evergreen scrub-shrub, regularly flooded wetland (presumably young mangrove plants). Open water is E1UBL: estuarine subtidal, unconsolidated bottom, the same as all of subtidal East Loch.

‘Aiea Bay and ‘Aiea Stream

The semi-enclosed embayment located in the northeast corner of East Loch is called ‘Aiea Bay being opposite the town of ‘Aiea. Features around the shore are (from west to east): McGrew Point Naval Housing, ‘Aiea Bay State Recreation Area, ‘Aiea Stream entering at the head of the Bay, Admiral’s Boathouse, and a Navy recreation area, the north end of which lies on an unnamed point marking the southern end of the Bay.

Small areas of mangrove exist off the developed park (see ID ..9024 through ..9027 above and ID ..9029, ..9030, and ..9031) that are not wetlands. Apparently the state has tended to cut mangrove in this area in order to maintain an open shore and views from the park. Further to the southeast, the mangrove growth forms a mangal wetland that is or was extensive around the mouth of ‘Aiea Stream (wetlands ..9032, ..9033, and ..9034). In 2007, all of the mangrove in this area was removed (Fig. 6-01). Englund et al. (2000) sampled aquatic biota in the estuary of this stream, described as “underneath the Kamehameha Highway bridge, ...the sides of this stream mouth are entirely encased in concrete.” Apparently the lower section of stream receives little

freshwater flow and stream mouth "was more marine in character, and surface salinities ranged from 27 to 30 ppt." Our survey noted a barracuda (*Sphyraena helleri*) in the estuary in this area.

Figure 6-01. View from 'Aiea Bay State Recreation Area across the upper end of 'Aiea Bay showing no mangrove trees present.

A small area behind the mangrove is designated as wetland ID ..9028. Inland from the northern end of the removed mangal is a drainage ditch that supports wetland plants (in January 2007, we noted duckweed on shallow pools and California grass; in July 2007, the area was heavily mowed, but supported pickleweed in the lowest section). This specific feature is indicated in the NWI as PEM1A: Palustrine emergent vegetation temporarily flooded (USFWS, 2007).

Before the extensive clearing in 2007, the mangal extended from the mouth of 'Aiea Stream along the shore to the east and then south onto Navy property (ID ..9034). When we did our first survey, we noted that a corridor had been cut through the mangrove growth to the open water of 'Aiea Bay (Fig. 6-02). This action was an initial test of the method for the complete removal of the mangal.

The shoreline mangal ends a short distance beyond the Navy security fence, where isolated small mangroves are present on a concrete debris shore (Fig. 6-03).

Figure 6-02. Test cut through the mangal (ID ..9034) out to open water of 'Aiea Bay in January 2007. McGrew Point in background. This entire mangal has since been removed.

An area of mostly what appears to be concrete debris lying off the point between the Admiral's yacht pier and the Navy marina supports a growth of red mangrove shrubs (ID ..9023). Although not visited in 2007, it appears these plants represent opportunistic settlements on an artificial islet similar to the situation depicted in Fig. 6-02 and have not yet develop into a mangal wetland.

The Navy recreation area south of 'Aiea Bay includes a boating facility (yacht basin with docks) extending southward to the Admiral Carey Bridge (connection to Ford Island). A mostly coral rubble shoreline with scattered bulkheads (with a few mangrove shrubs) extends southward fronting the USS *Bowfin* Submarine Museum and USS *Arizona* Visitor Center. A small project involving mangrove removal between the two museums was undertaken by Hunt Building Co., leaseholder on the parcel between the two museum parcels.

Figure 6-02. Shoreline near the very north end of Navy property on the east side of ʻAiea Bay showing opportunistic establishment of red mangrove on concrete and boulders. Mangal in the background has since been removed.

The NWI (USFWS, 1999) did not previously indicate any wetlands present in ʻAiea Bay, but the updated inventory does (USFWS, 2007). The mangal on either side of the mouth of ʻAiea Stream is coded E2FO3N: estuarine, intertidal, broad-leaved evergreen forested, regularly flooded wetland (i.e., mangal). Open waters are E1UBL: estuarine subtidal, unconsolidated bottom, the same as all of subtidal East Loch. The area of scattered mangrove shrubs on mostly

concrete debris and sand is E2SS3N: estuarine, intertidal, broad-leaved evergreen scrub-shrub, regularly flooded wetland.

Halawa Stream

The *U.S.S. Arizona* Visitor Center is situated on the shore at the mouth of Halawa Stream, and the transport boats out to the memorial off Ford Island utilize a pier in the Halawa Estuary channel. The shore of the estuary is lined with bulkheads up to a former footbridge, further upstream of which the shore is mostly natural (*AECOS*, 1999).

Kamehameha Hwy. (State Rte. 99) crosses the estuary close to the *U.S.S. Arizona* Visitor Center, and upstream, there are no additional crossings until Salt Lake Blvd. The pedestrian crossing located just downstream of Kamehameha Highway (ACOE, 1999) has been closed and the foot bridge removed; the fuel pipeline crossing remains. Tidal influence in Halawa Stream extends upstream to the concrete footings of the Salt Lake Boulevard bridge (Englund et al., 2000). Halawa Stream is confined to a concrete culvert upstream of Salt Lake Blvd. The following description of the area in the vicinity of the Kamehameha Highway bridges is taken from AECOS (1999):

> The stream in the project area is 30 to 40 m (100 to 130 ft) across and clearly tidal. Stream flow, *per se*, was not evident during the visits. However, areas of rock strewn mud flats on either sides of the channel (but most particularly on the north side under the highway viaducts) were exposed at low tide and submerged at high tide. The shoreline is mostly fill material in the immediate project area, with numerous functional and abandoned old pipes and drains located along the shore.
>
> Downstream (west) from the viaducts, red mangrove (*Rhizophora mangle*) forms several groves that occupy most of the shoreline, with pickleweed (*Batis maritimus*) covering the ground along the inland mangrove border and at the shore between the trees. At the mouth of the stream, concrete bulkheads line the shore. Upstream of the highway viaducts the channel widens to some 90 m (300 ft) across. The riparian zone is mostly steep banks of lateritic soils supporting scattered trees and weedy herbaceous species such as `uhaloa (*Waltheria indica*), false alena (*Boerhavia coccinea*), little bell (*Ipomoea triloba*), plushgrass (*Chloris radiata*), and Guinea grass (*Panicum maximum*). A single cotton plant (*Gossypium* sp.) was observed in the project area. Riparian trees and shrubs present in this area include numerous kiawe (*Prosopis pallida*) and lesser numbers of koa-haole (*Leucaena leucocephala*), milo (*Thespesia populnea*), klu (*Acacia farnesiana*), ‘opiuma (*Pithecellobium dulce*), Indian fleabane (*Pluchea indica*), pink shower tree (*Cassia grandis*), monkeypod (*Samanea saman*), and Christmasberry (*Schinus terebinthifolius*). ... Substantial amounts of litter and flotsam, including a stripped automobile, are

present beneath the highway viaducts. Stream banks are mostly soil, and vary from only a meter or so above high tide to over 10 meters on the south shore upstream of the project area.

A small wetland area on the left bank immediately upstream of the former pedestrian bridge was investigated in January 2007. Two wetlands are indicated by ACOE (1999) in this area and designated ..10050 and 10051. The former is an area of mangrove growing on a sand bank or bar in the estuary channel; the latter is a growth of mostly pickleweed behind the mangrove, but also includes some *milo* and Indian fleabane. This open area merges into the former channel bank. Plants growing clearly above the wetland here include Indian fleabane, kiawe, and Guinea grass. An area of vegetated wetland shown by ACOE (1999; ..10050 in part) between the east and west bound highway viaducts has since been removed because these highway bridges, at the time of our survey, are undergoing replacement.

The formation of stream bars at this particular place in the estuary has afforded the opportunity for mangroves to establish. The channel banks across the channel and upstream are generally too steep and rocky. The channel towards the mouth from the pipeline crossing is dredged on occasion, and this part of the estuary is one of shoreline bulkheads. The designated wetlands support obligate wetland plants as dominants, but these are growing on relatively coarse sediment deposited as a beach, and therefore not hydric soil. It is also unclear if the higher feature (ID ..10052) is intertidal, although some minimal flooding at extreme high tides might occur. ACOE (1999, p. 49-50) came to a different conclusion despite stating first that "[m]angroves can be found in other waters of the U.S. including streams, rivers, embayments and shorelines...but of themselves do not constitute a regulatory wetland." For this "wetland", the report stated "[i]n areas where there is a buildup of sediment caused by mangrove encroachment, the stream or shoreline may change from a waterway to a wetland." Soil pit sample points showed (in 1999) soil of low chroma with possible gleying. We contend that this location represents a natural sediment bar of coarse material (not soil) upon which mangroves have established, and is not a "buildup of sediment caused by mangroves."

Halawa estuary water quality results are provided in AECOS (1999). Surface salinities near the Kamehameha Highway bridge and in the area of the USS Arizona Memorial ranged between 30 to 37 ppt, while salinities near the Salt Lake Boulevard McDonald's ranged from 0 ppt in the weakly flowing freshwater channel to 26 to 32 ppt slightly downstream (Englund et al., 2000).

The NWI (USFWS, 1999) showed no wetlands in or around Halawa Stream, but the small wetland described above for the left bank between the pipeline

crossing and the west bound viaduct of Kamehameha Highway is now shown (USFWS, 2007) as E2SS3N: estuarine intertidal regularly flooded, broad-leaved evergreen scrub-shrub (pickleweed and/or shrubby mangrove). The stream estuary is coded E1UBL: estuarine subtidal, unconsolidated bottom, the same as all of subtidal East Loch. The estuary is mapped as extending approximately 900 ft (300 m) upstream from Salt Lake Blvd., and a narrow band of presumably mangrove shrub is indicated along the right bank above the bend in the estuary (USFWS, 2007) .

Shipyard

Directly south of Halawa Stream mouth and extending southward along the Harbor shore are the piers and docks of the Naval Base. Only a very few scattered, short sections of shoreline are not concrete bulkhead, and therefore cannot support mangal or other vegetation. No streams exist in this area[1], and no wetlands are present. Included here is what is sometimes referred to as Southeast Loch, an embayment a part of which is the Pearl Harbor submarine base. Further south and west along the shore is the Pearl Harbor Naval Shipyard. Only at Hospital Point to the west of the shipyard is there shoreline that is not hardened by porting facilities.

ACOE (1999, p. 50) includes only the following regarding this entire area:

> Based upon a request from PACNAVFACENGCOM, we visited the shoreline from the pier near Building 478 to pier K12. The shoreline is presently covered by construction debris with *milo* occurring in the area. The top of the slope was 4-8 feet higher than the water level at the time of the visit. Because most of the area is paved or hardened, wetland hydrology and soils are not present thus these areas are not considered wetlands.
>
> The remainder of the shoreline up to South Avenue appears to be hardened with the exception of portions of the Hospital Point Housing area. We visited this site and found that the landward portions of the area drops down 2-4 feet to a coral and sand substrate. Mangrove and *milo* exist in relatively sparse clumps. This area and the shipyard area as a whole, does (sic) not contain any jurisdictional wetlands.

The NWI (USFWS, 2007) shows no wetlands on the main base, although unconsolidated shore areas (beaches) are shown.

[1] The ACOE (1999) did locate a drainage outlet under H-1 Freeway feeding a small stream between Makalapa Drive and H-1 flowing in a natural channel to the vicinity of Radford Dr. on the Naval Reservation. The Corps concluded the stream was jurisdictional (waters of the U.S.).

Makalapa Crater

Makalapa Crater is a former cinder cone located east of Kamehameha Highway and west of H-1 Freeway a short distance south of Halawa Stream. Makalapa is one of three eruption cones located close together, the other two being Aliamanu and (Salt Lake). The eruption of these cones diverted more mauka stream flows to the east, away from Pearl Harbor. It is likely that all three once contained wetlands. Aliamanu crater floor is fully developed as a Naval Housing area. Salt Lake once held a saline pond, but this has been mostly filled for private development including a golf course which incorporates the last remants (now freshwater) of the former body of water. Most of Makalapa Crater floor remains undeveloped. A fishpond once located here (Sterling and Summers, 1978) disappeared under 30-40 ft of sediment from harbor dredging (VTN Pacific, 1977). ACOE (1999) investigated a small patch of ground supporting pickleweed and California grass, suspecting that a wetland might be present. However, no evidence of recent flooding or hydric soil indicators were found, and the team concluded the site "was a remnant patch of vegetation that at one time, may have been part of a larger wetland that no longer exists."

A stream that flows through a small neighborhood park between H-1 Interstate and Radford Drive discussed in ACOE (1999) was revisited in January 2007. The stream was flowing and seen to support small populations of several "wetland" plants (*'ae'ae*, umbrella sedge, primrose willow), but is a stream and not a wetland.

The NWI (USFWS, 2007) no longer shows wetlands in this area.

Bishop Point and Outer Pearl Harbor Entrance Channel

On the south side, the shipyard and naval base end at South Ave. Beyond is Hickam AFB. This shoreline, from the shipyard down to and around Bishop Point, is defined by old bulkheads. South of Bishop Point is a small piece of Navy property with concrete bulkheads and docks (in part described in *AECOS*, 2002b). Two large, old concrete docks frame the Fort Kamehameha wastewater treatment plant located on another Navy parcel behind a concrete wall shoreline. There is a moderately large drainage outlet from Hickam AFB on the north side of the WWTP.

The more southerly of the old concrete docks, now abandoned and overgrown, marks the start of a broad coral reef that extends nearly 1500 ft (450 m) out from the shoreline on the east side of the Pearl Harbor entrance channel opposite Hammer Point at Puuloa (Chap. 1). The shoreline at Hickam in from the reef flat is, for the most part, a sand beach. The southern end of the beach,

part of old Fort Kamehameha, supports a mangal extending in places over 400 ft (120 m) out from the beach shoreline (Fig. 6-03). This mangal wetland is opposite Seaman Ave. in Ft. Kamehameha where the road turns from roughly N-S to E-W. This shoreline mangal is outside of the project study area and therefore was not investigated further.

Figure 6-03. Aerial view of mangrove growth extending onto the reef flat off Fort Kamehameha at the mouth of Pearl Harbor (4/11/07).

The NWI maps a change in the Pearl Harbor entrance channel with a line across the channel from the abandoned concrete dock, the inner zone being E1UBL (estuarine subtidal unconsolidated bottom) and the outer zone M1UBL (same, only marine system instead of estuarine system). The reef south of the dock is M2US2N: marine intertidal regularly flooded unconsolidated sand shore. The mangal off Fort Kamehameha is E2SS3N: estuarine intertidal regularly flooded, broad-leaved evergreen scrub-shrub (USFWS, 1999, 2007).

Ford Island

Ford Island (*Moku'ume'ume*) is an offshore island located in East Loch of Pearl Harbor that approaches, in size, the area of the Pearl City Peninsula (Chap. 4). The island is a developed part of the Naval Base at Pearl Harbor, and the

shoreline reflects a long history of ramp, pier, and dock construction, bulkheads and revetments, and land fill. The interior is completely developed as an airfield, other Navy facilities of various sorts, including new Navy housing projects (Fig. 6-04).

Figure 6-04. Satellite image of Ford Island (Microsoft Corp., 2006) showing relationship to adjacent areas of Pearl Harbor and U.S. Navy facilities that completely cover the island.

In the 1999 survey of Pearl Harbor wetlands (ACOE, 1999), all of the shoreline of the island (excepting the pier and docking facilities along the east side from the southern tip to Pier F-5—*U.S.S. Missouri* berth) was carefully surveyed to ascertain if any wetlands were present. The fact that a separate Segment was devoted to Ford Island in the 1999 report suggests the Navy had a special interest at the time in whether wetland resources were present or not. The conclusion of the 1999 report (ACOE, 1999, p. 54) was that "...the [Ford Island] shoreline has many plants that are commonly found in wetlands such as pickleweed, American [red] Mangrove, Indian fleabane and *milo*. Investigation of

these areas found that hydric soils and hydrology indicators were lacking and thus, wetlands do not presently exist at Ford Island."

The latest version of the NWI (USFWS, 2007) indicates shoreline and shallow reef features and a couple of mangrove wetlands on the east shore, including one small area coded E2FO3N (a mangal) and E2EM1N (estuarine intertidal emergent vegetation regularly flooded). These look more like *kiawe* in our photographs and are not wetlands as defined by ACOE (1987).

Ford Island was not surveyed for our report for the reason that neither ACOE nor USFWS (1999) recorded any wetlands on Ford Island or along its shore, and that no recent changes in hydrology are known that could potentially alter this situation. However, a narrow strip on the island directly adjacent along the south side of the ramp to the Admiral Clarey Bridge, is a ditch coded R4SBCrx (Riverine intermittent streambed seasonally flooded artificial substrate excavated) and E2SS3Nx (an excavated estuarine intertidal regularly flooded, broad-leaved evergreen scrub-shrub). Actually, this area is a concrete-lined drainage swale feeding to a short remnant of the original shore, providing drainage along the road fill that was placed along and just off the shore on a former shallow reef platform. Why a normally dry, concrete drain would be considered an aquatic environment at all is unknown. However, subtidal concrete drains are normally coded E1UBLx, and upstream lined stream channels coded R4SBCrx (e.g., Aiea Stream at Moanalua Road).

Table 6-02. Summary of changes since 1999

Site	Description	Change since 1999	ACOE ID No.
Loko Pa'aiau	Former fishpond, over-grown with mangrove	No change	**..8001**
McGrew Point	Scattered mangrove growth along shore	Potentially one area (..8007) consolidating towards a mangal	**..8007** to ..8022, ..8045, & ..8046
'Aiea Bay	Extensive mangal at head of embayment.	All mangrove removed in 2007.	..9024 to ..9034
Halawa Stream	Mangals along the estuary	In part removed by bridge recon-struction.	..10050 & ..10051
Makalapa Crater	California grass and pickleweed patches; not wetlands.	Not known, but unlikely changed into wetlands.	..11200 & ..11201*

* Misnumbered by ACOE (1999) on their index map as ..01200 & ..01201

No supplemental photographs (SP) submitted for Chapter 6.